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PREFACE

The impact of science and technology on our society has been the subject of much study and discussion. The public, generally, and those engaged in social work in the broadest sense have become increasingly aware of the preoccupation of our society with technological achievements. Correspondingly, there is an increasing concern over the effect on man and his behavior and on social processes. The need for understanding the methodology and the potential of science and technology by society at large is quite clear.

When the national program of space exploration and research was given its tremendous impetus by our commitment to send men to the moon by 1970, it was recognized by many that a process of technological development was set into motion of dimensions greater than anything we have had since World War II. Mr. James E. Webb, the Administrator of the National Aeronautics and Space Administration, was acutely aware of the potentialities of the program and its impact on the economic, political, and other social processes. It was his inspiration that led us to develop an interdisciplinary group in the social sciences within the framework of the Space Sciences Laboratory. The social scientists working in the environment of the physicist, chemist, biologist, and engineer have been able to understand better the "demon" whose effect is of such concern. The scientist and engineer, or at least some of us, have been awakened to the larger sphere of influence of our work and have been led to give more than passing thought to the problems. This work carried out under the University program of the N. A. S. A., under grant NsG-243 in our case, has made clear the problems of semantics and communications among men of different intellectual backgrounds and disciplines. It has brought into focus the need to clarify ideas and to develop a better understanding of the content of other fields of knowledge.

The problems of communication become even more complex when one seeks to establish intellectual rapport between members of the academic world and those outside. The barriers between church and religion and the university are made higher and thicker by an unfortunate construction of the principle of separation of church and state and, as a result, there has been far too little interaction between the university and the theological institutions. It was, therefore, a pleasant and most welcomed opportunity for the members of the Space Sciences Laboratory to have a direct exchange of ideas with the Deans of the Cathedrals of the Episcopal Church. It was an opportunity to exercise the philosophy and purpose of our interdisciplinary program in another highly important sphere.

Samuel Silver, Director
Space Sciences Laboratory

THE IMPACT OF MODERN SCIENCE AND TECHNOLOGY ON SOCIETY

Samuel Silver

The idea of holding a symposium on modern science and technology as part of the Annual Conference of the Deans of the Cathedral of the Episcopal Church, and also the scope of the program, developed out of many discussions between Father Weaver and me on the general question of how to establish lines of communication between the world of the university and the world of the church, and between both of them and the larger world of human affairs of which we are a part. The Space Sciences Laboratory at Berkeley has been concerned with questions and issues of this nature for a number of years. An important component of its program is the study of the utilization of the technological developments arising from the space program in the treatment of urban problems and of the application of various methodologies used in research and engineering to the processes of many of our social institutions.

The members of the Laboratory and my colleagues on the faculty responded with interest and pleasure--I should say, indeed, with enthusiasm--to my proposal to prepare this program for your Annual Conference. It is my pleasure to express for all of us our welcome to you and our delight in having the opportunity to present our several areas of research, and to express our thoughts on the implications of our work with respect to social attitudes and the general philosophical content of our civilization. Our response to the idea of taking part in your conference reflects a deep concern that many of us have about the effects of our work and their consequences in the larger realm of human experience and activities extending beyond the laboratories and classrooms. The effects of science and technology on the social, political and economic sphere, depend as much on the understanding by society of what we are doing, on the interpretation, and, I should say even translation, of our studies, results, and discoveries by people like yourselves as on the physical and intellectual artifacts which we generate. We are very cognizant of the need for discussions and exchange of views among the various segments of society. We hope that this conference which is perhaps unprecedented in form in the university will help to generate a much needed dialogue between the clergy and the academicians.

It would be surprising if this type of meeting were not viewed with skepticism by many, even be regarded as being inappropriate by both theologians and scientists. The myth of the conflict between science and religion persists. There is often a failure to recognize that the conflict is between institutions which have resulted from the organization of a philosophical set of concepts and ideals into a social practice under a system of practitioners. My personal view, based, to be sure, on my religious concepts, is that there is no conflict between the philosophical content of science and the philosophical content of religion. There is a conflict between science and superstition. In my mind there is likewise a conflict between religion and superstition. Religion, I believe, directs itself to the question of man's role and purpose in the universe. Its objectives are to set what I should call the "terms of reference" for man, to establish a basis for purpose in man's relation to man, founded on a philosophical construction of man's position in the universe. While religion deals necessarily with concepts and modalities of thought that lie beyond the domain of the natural sciences, the philosophical construct of the deity and the attendant theology emerge from man's desire to establish his position in relation to his physical environment and the phenomena of nature; and, therefore, religion and theology must take cognizance of the facts and findings resulting from the pursuit of scientific research and investigation.

The natural sciences illumine the understanding of the physical and biological universe. The natural sciences do not explain the universe in an ultimate sense, but, rather, based on the premise that there is an order to the structure of the universe they seek to discern that order and to explain one set of phenomena or set of behavior patterns in nature in terms of what may be considered to be more primary patterns. As the course of scientific research unfolds new patterns, and uncovers new phenomena, men cannot help but measure their traditional beliefs and teachings against the new knowledge. The problem is accentuated today by the situation that science as well as technology has become an item for the newsman and the broadcast commentator. The public is thus fed information which, even if it were being presented precisely and accurately, is still in a raw state. It takes time and thought to place each development in proper perspective with respect to the rest of the science and, certainly, even more thought to integrate the new ideas and data into the sense of experience that is the individual's basis for action. It takes time and thought to assess the potentialities of the knowledge and its impact on our society. The theologian on his part must understand both the process of scientific research and the structure of the knowledge that results therefrom in order to validate for man those premises on which his religion rests. It is necessary to interpret scientific discoveries as a fulfillment of mankind and to re-interpret teachings and beliefs in the light of the knowledge of the day. This in no way gives science priority over religion and theology. I would submit to you the proposition that the theologian who understands and appreciates science for what it is will not find conflict with his basic premises, but will, rather find an affirmation of them in the continuously unfolding scene of man seeking to understand nature and discovering the beauty of order, though complex and intricate, in the microscopic and macroscopic structure of the universe.

Much has been said and is being said about the potentialities of science and technology for the realization of man's hopes and dreams. The material accomplishments are here for all to see. We can lighten man's labor, surround him with more physical security from the forces of nature, increase his life span further, diminish the ravages of disease. I certainly need not try to convince you that these are accomplishments, not idle fantasies. But, it is the strange contradiction of nature that each development that should be a step forward brings with it more problems, perhaps a step backward in another direction. Good harbors its own evil and evil often plays wet nurse to much good. The effects of science and technology on the mind of man, on his individual behavior and his collective behavior which we call society, are overwhelmingly complex. Man's behavior becomes itself a central issue. The interaction of man with his environment has become so far-reaching, so intimate that the activity of man has become a dominant component of the process of physical and organic change on this planet. The interaction of man with man has developed intricacies and complexities of relationships of such nature that the great principle of the dignity of man and the sacredness of life seems to be threatened from all sides. It is pointless to lay the blame on science and technology as such. They are expressions of the human spirit, just as are art, music, and literature, in response to the stimuli of the world about us. It is because man and his social institutions are themselves natural phenomena in the largest sense that there is such a complex of interdependency among the components of man's activities and such a process of creation of our own problems. The clergy to whom man has been wont to turn to for solace, for a philosophical perspective on his position in the scheme of things have lost their way as have so many, if not all of us. It is, therefore, on this aspect of the impact of science and technology on our society that I am led to dwell here.

It is also necessary for me to comment on the manner in which the space age, or in less histrionic language, space research has furthered the situation. Space research has expanded enormously the boundaries of certain areas of our knowledge but it has not changed materially the fundamental principles nor the philosophical fabric of any basic science. But, it has been singularly dramatic in the measure of human experience in its challenge to the physical capabilities of man. The past decade has been singularly dramatic in the pace it has set in scientific research and exploration of the universe and in the rate of realization of a technology that was largely foreseen for many years but was before slow in coming because of the absence of the challenge for the accomplishment. This technological achievement has given us great material wealth. That wealth engages every aspect of our lives, and, as wealth always does, it has become an indelible component of man's concept of his needs. The enormity of our riches and the swiftness with which they have accrued has affected our relationships to one another, our values and our purpose, and is causing man to lose sight of himself. And, I must repeat that the most salient feature of our so-called space age is the pace that has been set, the rate of development that gives us little opportunity to absorb the significance of what is happening and little opportunity to reflect on ourselves and our reactions.

I now wish to pass to a more detailed exposition of the several areas of problems which I have indicated in the foregoing remarks. First, I shall speak about the new findings in several fields of science from the point of view of their impact on man's thinking and philosophical base. The heavenly bodies and the sense of reaches of space beyond our earth have always been among the primary elements in the religious consciousness of man. It is evidenced today in the mythology, folklore, and still existent superstitions centered on this subject. The tremendous sense of excitement associated with manned exploration in space arises from this same primary component in man's search for his position in the universe. Our understanding of the physical universe beyond the earth has been enriched and greatly modified over the past twenty years by the combined work of radioastronomy and the exploration of the solar system by means of satellites and space probes. Professor Weaver will develop in some detail the current knowledge and understanding of the physical universe. I shall just touch upon some of the findings.

Space research has revealed that the interplanetary region is not the void we had thought it to be but is occupied by a tenuous gas, in highly ionized form, which is an extension of the atmosphere or outer layer of the sun. This work has led to new understanding of those terrestrial phenomena which are connected with activity of the sun, and we now know of a whole set of mechanisms or processes which link phenomena on the earth and in its atmosphere with the sun by way of the interplanetary medium.

The space probes which traveled to Venus and Mars have yielded new information about these planets, about the temperatures, and, in the case of Mars, the structure of the surface, and about the structure and composition of their atmospheres. On the one hand, the new information strikes at several theories regarding the genesis and development of the solar system and, on the other hand, the information eliminates the possibility of the existence of complex forms of life on these planets, such as we know on earth. The planets may be supporting some of the more primitive earth-type structures such as bacteria but the age-long speculations and hopes of finding advanced forms of life on our neighboring planets seem to have reached an end.

The new astronomy deals with regions of space far beyond those probed by our most powerful optical telescopes. Recently, new sources of energy have been discovered of such strength as to indicate that processes which we have not even thought of before are operative in these distant objects. We receive radiant energy of certain wavelengths from space which is suggestive of stars in the making and we receive radiant energy of other wavelengths which point to an explosive creation of the universe in the distant past. The term "creation" here refers not to the creation of matter but to the dispersal of matter over an extended region from a more concentrated configuration. I am sure that you recognize the need for adjustment of beliefs and attitudes to these discoveries. Your texts must be modified by interpretive readings if they are to command and retain the respect of your people.

Turning from the macroscopic universe to the microscopic universe, we direct our attention to some of the recent work in molecular biology. I wish to call your attention particularly to the work which has built a biochemical foundation for the understanding of genetics. Research has revealed the presence of a basic protein molecule in all living matter. The skeletal structure of the DNA molecule as it is called is essentially the same in all species. The differentiation among the many forms of life is associated with types of smaller molecular units, the amino acids, and the locations on the skeletal structure at which they are attached. This pattern of type of amino acid and point of attachment is known as the genetic code and it is replicated in every reproductive process and so transferred from one generation to the next. A rearrangement of the positions of attachment and a transformation of the type of amino acid may result from physical and chemical processes such as bombardment by cosmic rays, or artificially generated streams of particles, or by x-rays. The change in pattern may result in death or it may be compatible with the rest of the cell. In the latter case it may replicate in a reproductive process resulting in a mutation, that is, a change in structure that may become in fact a new species. Professor Jukes will tell us much more about this in his talk. I have given this brief introduction to his subject to direct your attention to two points. One is that here in this microscopic realm we have a most beautiful expression of order. It certainly sets a philosophical motif for the reflective mind which regards this as well as the grand dimensions of galaxies and the phenomena of the physical universe as relevant to man's place in nature. The other is that we recognize that the understanding of the genetic process at this biochemical level has awesome implications. It has been possible to make controlled genetic changes in very elementary living systems, and already there is much talk about genetic control at the human level. This is one instance of my earlier remark that the principle of the dignity of man and the sacredness of life seems to be threatened. Indeed, it is true that genetic modifications may make it possible to eliminate malformations and the miseries of inherited susceptibilities to certain diseases. But, the same knowledge can be used for monstrous schemes whose justification will be made in the name of the good of the society. I certainly do not need to spell out further the challenge this presents to all of you.

Professor Calvin will be speaking later about a third area of research which in a certain sense lies between and bridges the investigations of the physical universe and the microscopic domain of molecular biology.

His subject, Chemical Evolution, deals with the investigation of the development of life, more generally of organic matter, by searching for and identifying fossil molecules in rocks, sediments, and meteorites. The class of molecules of direct interest are those which in the light of present knowledge are associated with the life process, and their presence is strongly indicative of the existence of an organism almost as if the organism had left a skeletal imprint in the medium. The work on terrestrial material has uncovered such fossil molecules in the oldest known rocks and sediments, and, as a result, the date of the emergence of life on earth has been pushed back by even a billion years. This in itself is a remarkable discovery. But, perhaps even more moving is the fact that molecules of a related class are found in meteorites, the bodies falling into the earth from outer space. The work on the meteorites is still in an early stage but one can easily see some of the ramifications of the findings if indeed they should prove to be true beyond any doubt of experimental technique and error.

These several examples I have chosen are but a few of the vast realm of discoveries made in the physical and biological sciences in recent years. I want to emphasize that purely as knowledge, without regard to possible application and technological developments, they engage men's mind and cause him to question religion and theology. If the church fails to make its peace with science in this area and develop understanding, it is likely to be rejected and fail in other areas as well.

The technological aspects of our age are yet another matter to be considered. I have pointed out already that the technological advances have increased greatly our material wealth. It is wealth of both a collective form and individual form. The needs of life go beyond the primary ones we have heard so much about. In a society in which the automobile has become a major economic and social tool the sense of need for an automobile may be as real as the need for food. Poverty in our country does not necessarily represent a starvation level of economic status.

The technological achievements have had another psychological impact--they have bred an arrogance in man. I now am speaking of a collective arrogance. We have conquered space and we are certain we can do anything and everything. Indeed, the achievements have been monumental, and this reaction is certainly a natural, very human reaction. Arrogance is a double-edged sword. It is an essential component of creativity in the individual and in a society. But, it also can become an explosive force cutting away sympathy and compassion, and as a collective quantity it leads nations to extremes of irrationality. I am not criticising any one nation, for the whole western world (this includes the U. S. S.R.) has been seized by the fever. The nations of the western world approach the developing nations of Africa and Asia without respect and understanding of the values of the native cultures and press upon them their ideologies and their technological culture. False values of prestige and the political exploitation of science and technology have sullied man's great adventure and added to the babble of the international scene.

Of no less consequence, perhaps of even greater consequence, is the pace of technological activity and the shrinkage of distance by communications. The whirlwind of world events has taken on greater momentum in the consciousness of the individual by virtue of communication systems which bring news to and from the farthest corners almost within the hour of the occurrence of the event. Each of us, through radio and television, becomes a participant in the most awesome happenings. There is no time to reflect, no time to adjust, no time to let one set of emotions be completely exercised before another set are triggered. The human mind cannot handle all this bombardment, and the currents of emotions run confusedly through us.

One of the great technological developments made during the past decade under the stimulus of the space research program is the miniaturization of electronic components. Actually, it has been more than a process of miniaturization. Through advances in the basic science of the physics of semiconductors and related solid state materials and advances in the technology of handling such materials, it has become possible to make devices which, in what is almost a microscopic volume, perform the functions of systems of conventional electronic components. Sensors can be made which, together with transmitters to "broadcast" the information, can be packaged into tiny units which can be implanted in or attached to the body with little discomfort. Such devices can monitor many physiological processes. Computers no longer need large spaces to house them and it is possible to put together fairly general purpose computers that can sit on an ordinary desk and special purpose computers that are match-box in size. The whole art of the acquisition, processing, and storing of data has thus been transformed by the technology so that it is economically feasible to apply it to almost any process or system of processes. These developments are resulting in revolutionary techniques in medicine, in business, in many fields whose basic direction is for increasing the well-being and enjoyment of mankind.

But, these techniques which have extended the range of instrumentation from the macroscopic to almost microscopic dimensions have become something of Pandora's box. For there has been a corollary development in engineering known as systems analysis, the treatment of large complex problems involving large numbers of variables to establish optimal relationships among the variables. It is a technique whose power depends on computers. It has been used with success in planning military programs and large business ventures. It has caught the fancy of sociologists, educators, and politicians, and engineers turned into social scientists. Now we shall determine the objectives of education by systems analysis which will optimize in terms of the needs of the nation, or we shall solve juvenile delinquency by analyzing data on all school children and determine who is prone to be delinquent. We can attach sensors to people to monitor activities, to study the interrelation of individual and group behavior. The individual becomes a number and his person is no longer inviolate because his purpose, his needs as an individual, become secondary to the measurable needs of the averages or correlations that are the output of the data processing system. The criterion of system analysis is the optimum condition of the system, that is, the society. Here, indeed, arrogance feeds on itself and we have a potentially greater threat to the dignity of man than is posed by any physical weapon devised in our laboratories.

Dr. Hoos and Professor Churchman will speak about these techniques and the attendant problems. Dr. Hoos has been studying several programs in the aerospace industries whose theme is a systems analysis approach to a particular area of social problems. Professor Churchman will address himself to the ethics of large systems, the bases for ethics, and the modification of ethical values generated by the technological approach to social phenomena.

All of this sets before you a situation and a task of overwhelming proportions. It is often customary to attack science and technology as though they are the perpetuations of evil minds against their fellow men. But, science and technology are part of man's own exercise as a component of nature, of the universe. They are not to be denied and have their own beauty and majesty. The problem rests, rather, on an entirely different aspect of man's behavior. He needs his reference frame, a reference frame which sets for each individual a level of conscience and of responsibility. He needs guidance and perspective on how to utilize the fruits of his labors and the fulfillment of his potentialities. For you, the problem and the challenge is, as I said earlier, to interpret with understanding the massive impact of science and technology on society.

CHEMICAL EVOLUTION*

Melvin Calvin

N68-12083

The speaker's interest in the subject of chemical evolution grew out of other lines of investigation into the origin and development of life on the earth. One of these lines may be described as being a search for the possible pathways of chemical events by which complex organic molecules, and subsequently the more complex organization of these materials into the biochemical aggregates of living systems, were derived from the primeval atmosphere and surface of the earth having the rather elementary constituents of water, carbon dioxide, methane, and ammonia. Experiments performed in a number of laboratories by the speaker and other workers have shown that such a possible synthetic route could have been set on its way by ionizing radiation, particles or gamma rays and ultraviolet radiation, and by electrical discharges (lightning). Once a certain threshold of composition, a collection of organic building blocks, had been reached it was possible for the synthesis of complex structures to take place leading to the organization comprising a living system.

These ideas and directions of research lead to the extension of the thesis of evolution and natural selection to this formative period of living systems in which the synthesis of building blocks and the process of organization of the building blocks took place. The term, chemical evolution, refers to just that evolutionary history of the period during which the chemical constituents of the primeval earth were transformed into chemicals upon which living organisms, or from which living organisms, could develop.

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* This written essay was prepared by Professor Silver from notes on Professor Calvin's lecture and from Professor Calvin's Bakerian Lecture to the Royal Society given in London in 1965. Professor Calvin has not had the opportunity to review this essay.

On recognizing that chemical evolution is but an extension of the Darwinian thesis--indeed, Darwin himself recognized this point--it becomes almost obvious to continue the Darwinian approach to search the rocks and surface formations of the earth for the record. Just as Darwin and the biologists who followed him search for the records of species of recognizable forms of life, the fossil record, we are searching for the record of the more elementary stage, or rather of the stage prior to development of macroscopic organisms. We are searching for the record of chemical organizations along the pathway of the evolutionary process. This search has been made possible by the development in recent years of highly precise techniques for identifying organic materials and their intimate molecular structures even when the quantities of such materials are exceedingly small.

The geological history of the earth has been unfolded by many studies and techniques. A large collection of measurements, such as of the residual radioactivity and the percentage composition of various elements, establishes the age of the earth to be some five billion years. Figure 1 shows in summary form the geologic history. The period in which man appeared is very short indeed relative to the time and events that preceded. The period of chemical evolution is indicated as having started at a stage in the physical development of the earth which puts the earth into essentially the form it has today. As we move upward in the time-scale, the process of chemical evolution passes into the evolutionary process of differentiation and formation of species from the biochemical aggregates that achieved the degree of organization which we identify as a living system.

Organic compounds fall into several broad classes which we must consider. The foundation of organic systems is the special property of the carbon atom which makes it possible for carbon atoms to link together into large molecular units, carbon atom linked to carbon atom successively into an open chain or into closed configurations, or into helical arrays in conjunction with other atoms such as nitrogen, and so on. There are other atoms which also have an affinity for their own kind and can form somewhat extended structures but none other than carbon shows the ability to develop extended structures of the magnitude found in living systems and having the dynamic stability of the carbon system. Figure 2 illustrates some of these structures. The "fossil" molecules of interest are of all these types. Molecules having architectural form represented by Figure 2c are of special interest as the building blocks of proteins and another set of form of Figure 2e (though not illustrated specifically) are derivatives of nucleic acids, both sets being essential components of the biochemical organization of living systems. The molecules of the type Figure 2a and Figure 2b are of interest as leftovers of living systems that were subjected to the physical forces of heat and pressure in the development of the crustal layers of the earth. They are compounds that are representative of petroleum and related substances.

The search has been conducted in rocks of various geologic ages identified in Figure 1. Sections of two of these, the Green River Shale whose age is some 60 million years and the Soudan Shale whose age is 2.7 billion years, are shown in Figures 3 and 4, respectively. The organic materials are extracted from the rocks and separated into classes of compounds by various analytical tools. One of these tools is the molecular sieve, composed of structures having openings of molecular dimensions ($5A^{O}$) which allow the straight chain hydrocarbons to worm their way through and hold back the branched and cyclic structures. Figure 5 shows the analysis of the fractionated extracts obtained from the Green River Shale. The height of the peaks is a direct measure of the proportion of the compound found in the total extract. The top section of Figure 5 is a "first" cut of the composition of the total extract after the removal of non-hydrocarbon and aromatic components (these are cyclic compounds such as benzene shown in Figure 2d). The second and third sections of the figure are the analyses of the branched-cyclic extract and the normal chain extracts separated by the molecular sieve.

The significant features of the figures are both what is present and what is missing. It will be noted that analysis of the normal chain fraction shows a relative absence of compounds having an even number of carbon atoms and a special prominence of chains having 17, 29, and 31 carbon atoms. The particular significance of this is that it points to a biological origin of these compounds rather than a process of generation in a chemical system under temperature and pressure from which a more general and even distribution of structures would be expected to result. Perhaps even more marked is the selective features of the branched-cyclic fraction for the compounds which have been identified, as indicated on the figure, are quite certainly associated with biological activity.

The analysis of the Soudan Shale, shown in Figure 6, exhibits an even more specialized structure. The distribution over the normal chain compounds is very much contracted dominated by the C_{17} compound. The distribution of branched-cyclic compounds is also compressed but the isoprenoids and the pristane and phytane stand out clearly above the rest. They are the same compounds as have been identified in the extract from the Green River Shale. If the interpretation of the process of generation of these compounds which has been postulated by the speaker and his co-workers is correct, these analyses of Soudan Shale extracts are evidence of biological activity on the earth when it was 2.7 billion years old.

These analyses and findings not only place the beginning of the development of life on earth into an early phase of the history of the earth but also change the time scale of the rate of chemical evolution if the age of the earth is in fact the 5 billion years quoted earlier. It has been suggested that many of the organic compounds which we believe to be at the foundation level of organic evolution were present in the original cosmic dust which gave rise to earth itself. To test this hypothesis we have three directions in which to search. One is to search for samples of earth material even older than 2.7 billion years and carry out analyses such as those described here. A second direction is to examine the cosmic material falling into the earth--meteors and meteorites--for organic constituents. This work is also in progress and positive indications have been observed. The work is limited greatly by the smallness of the samples available and the possibilities of contamination which might have occurred before the meteoric material was found. The third is to study the materials comprising the surface of the moon. The moon has been devoid of an atmosphere for over a billion years and has been bombarded by cosmic material over all that time. It is, therefore, a repository --an archeological museum--of material from all over the universe, free from the contamination that is likely to occur on the earth. On the moon--in the surface material--we may find records carrying us back into time and space and perhaps linking the origin of life on earth with sources and processes extending over vast reaches of the universe.

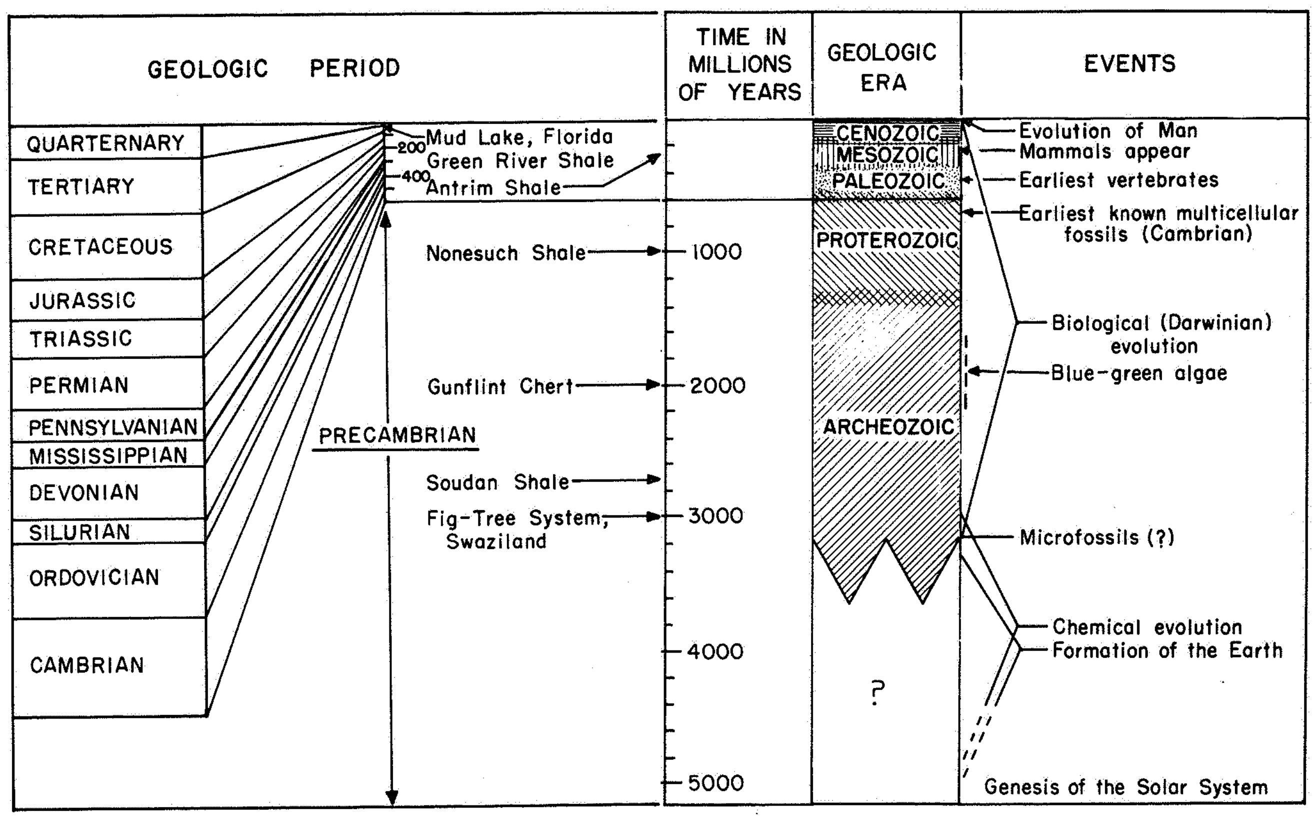
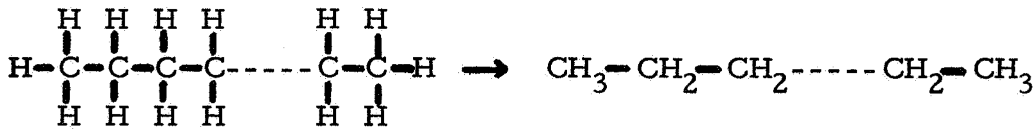
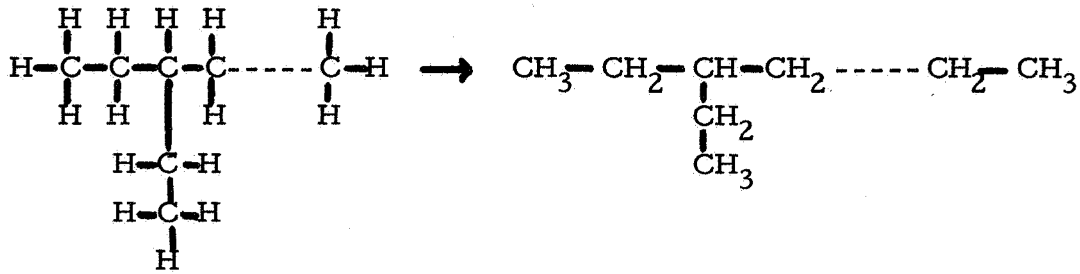


Fig. 1. Geologic History of the Earth

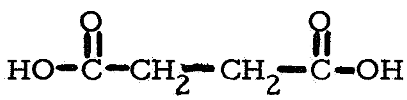
(a) saturated hydrocarbon



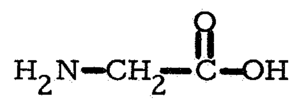
(b) branched chain hydrocarbon



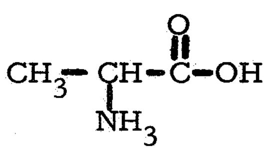
(c) primitive organic molecules of importance to the synthesis of living systems



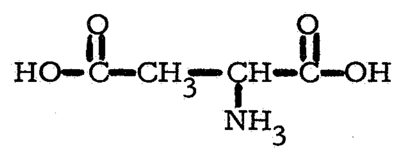
succinic acid



glycine

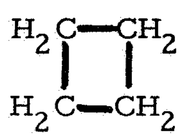


alanine

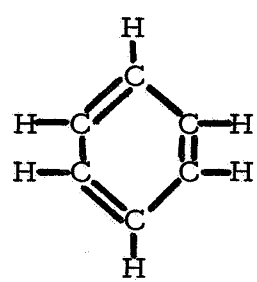


aspartic acid

(d) carbocyclic molecules

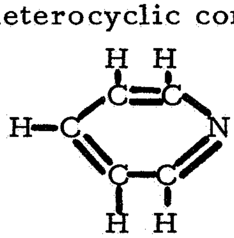


tetramethylene



benzene

(e) heterocyclic compounds



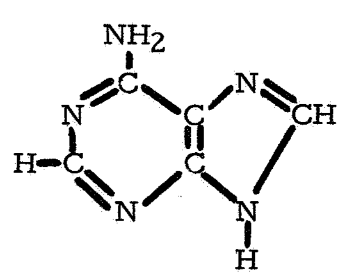


Fig. 2. Types of molecular structures

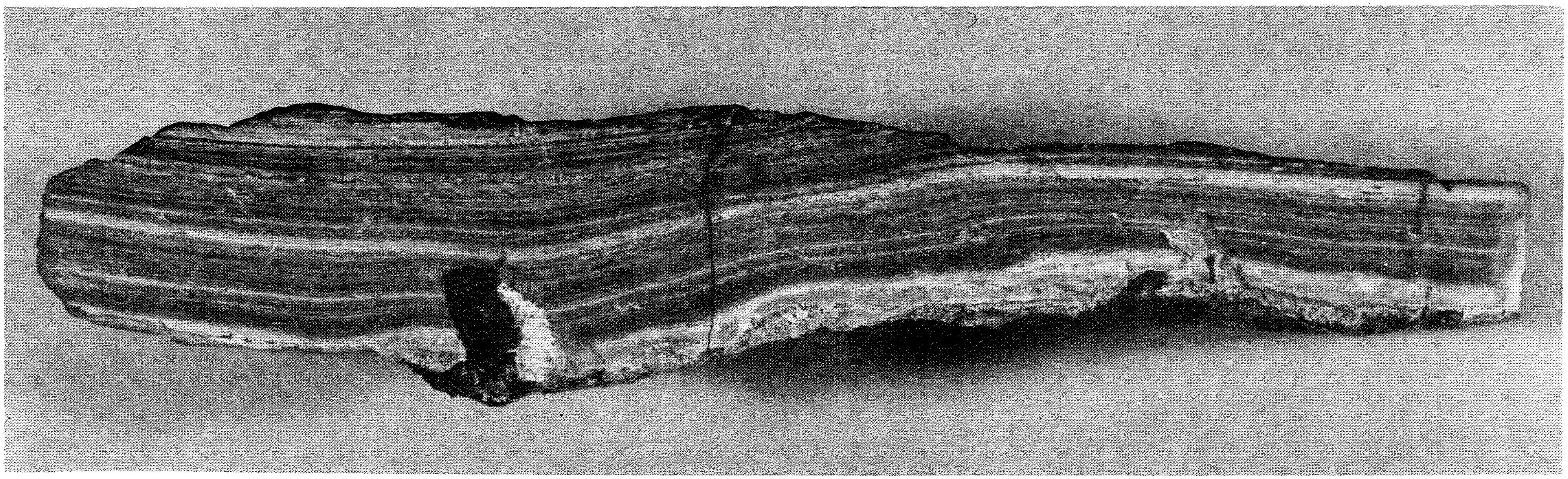
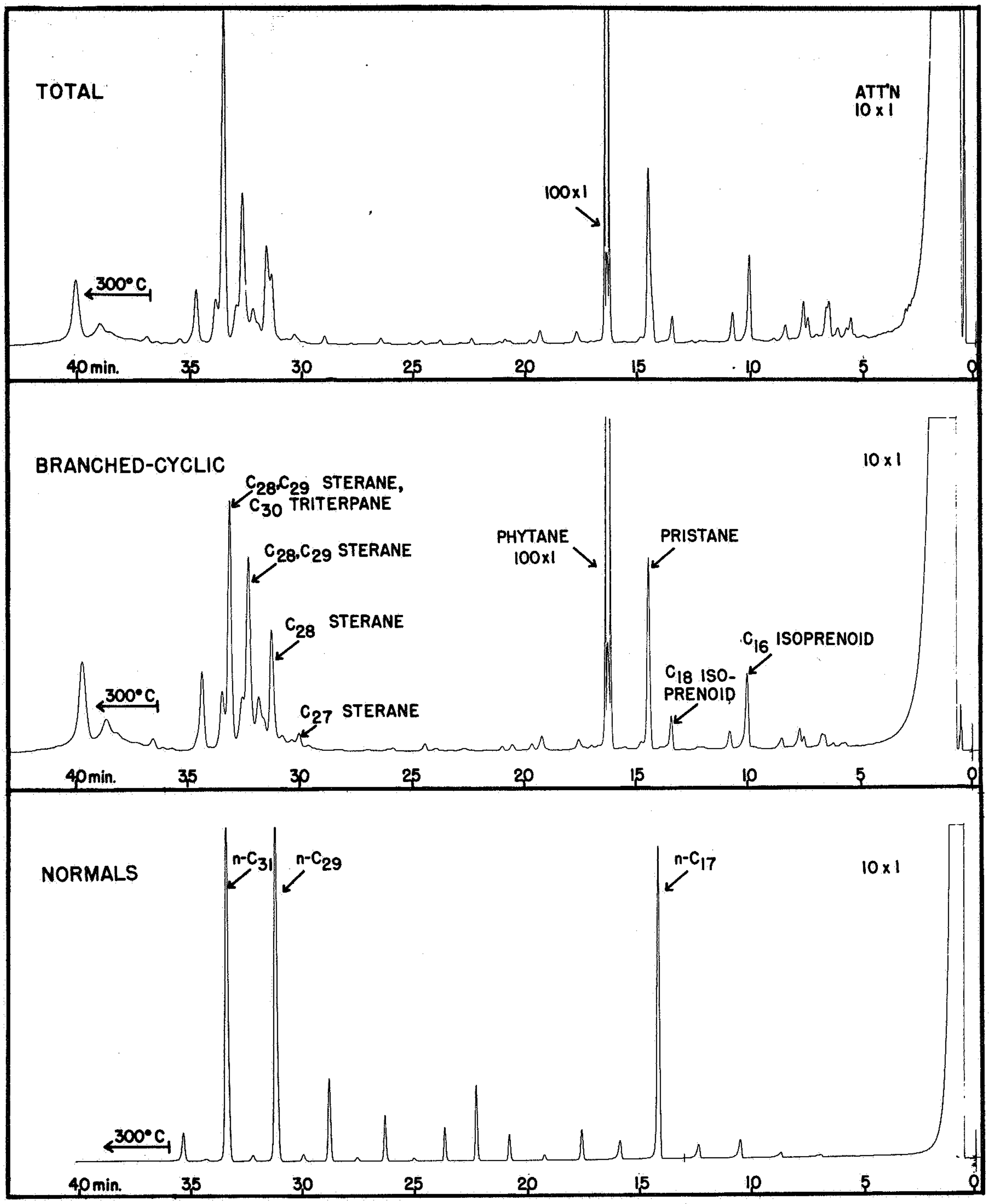


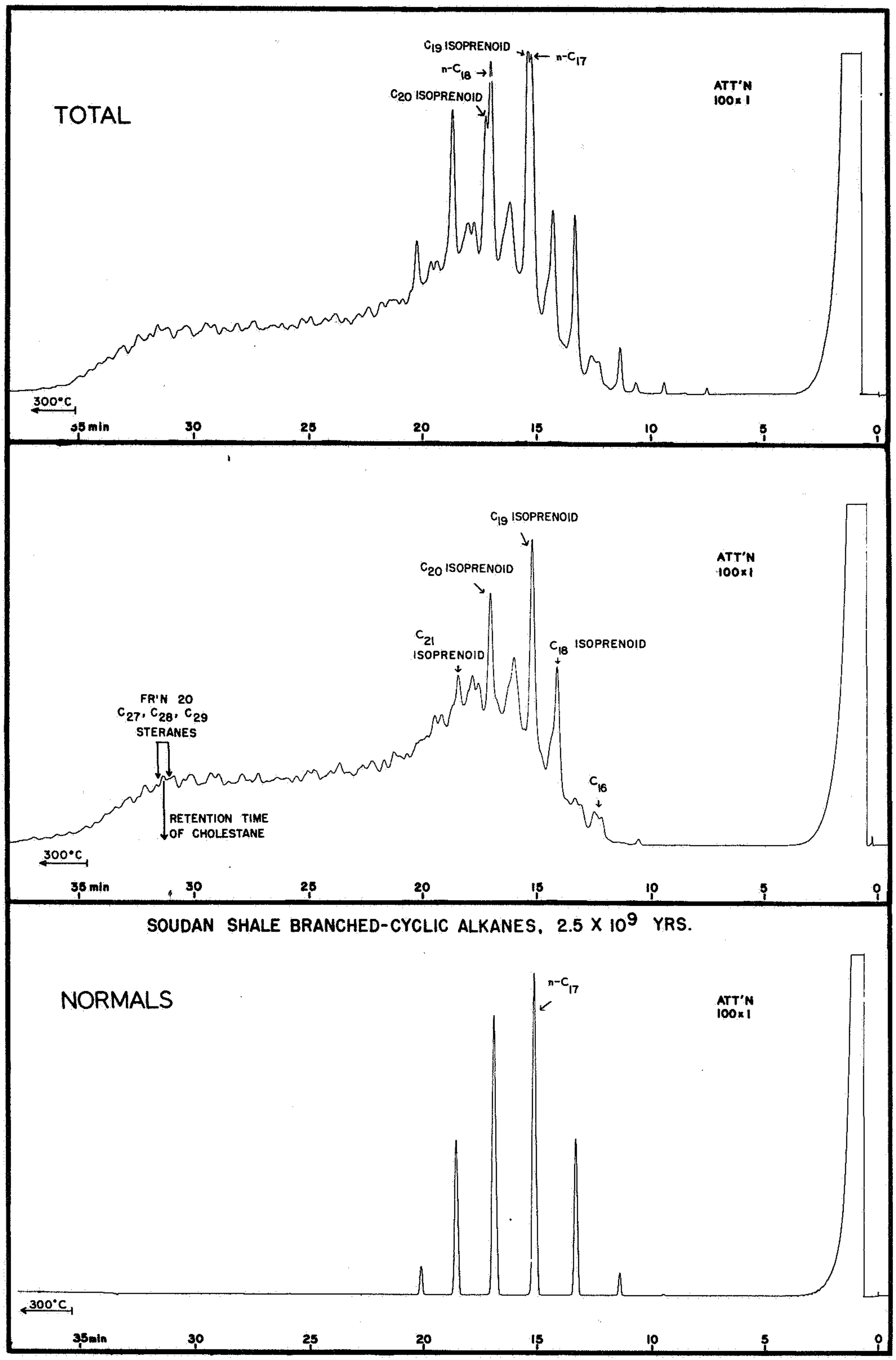
Fig. 3. Green River Shale approx. 60 million years old

Fig. 4. Soudan Iron Shale approx. 2.7 billion years old



GREEN RIVER SHALE (COLORADO), ~ 60×10^6 YRS. ALKANE FRACTIONS

Fig. 5.



SOUDAN SHALE ALKANE FRACTIONS

Fig. 6.

MOLECULAR BIOLOGY AND GENETICS

T. H. Jukes

N68-12084

The last speaker showed you many beautiful slides for which I have no counterpart. He dealt with a fascinating subject, and in the discussion which followed it was obvious that when we think of astronomy, or when we read about astronomy, we have somewhat the feeling that we have a comfortable seat in a planetarium. On the other hand, when we get to talking about biology, we feel more involved in it and we have no trouble about stirring up dialogue with people in other fields. My text is as follows:

> We have learned to bottle our parents
> twain in the yelk of an addled egg
>
> We have learned to whittle the Eden
> tree to the shape of a surplice peg
>
> We know that the tail must wag the
> dog, as the horse is drawn by the cart
>
> And the devil whoops, as he did of old:
> "It's clever, but is it art?"

It is taken from the Epistle of Rudyard Kipling to the Philistines. Kipling was a good communicant. My discussion will be confined to the first line. The second line, I believe, is in your department; the third refers probably to the general theme of relativity; and the fourth, of course, alludes to the stirrings of conscience that take place in human beings when they contemplate their place in nature.

Within the last 15 years a complete revolution has taken place in biology. The revolution started as a result of the discoveries by Mendel, who was an eminent cleric and who revolutionized the biological sciences on the side. He showed that inheritance took place by means of what came to be known as genes. From then on the search was to find out what the genes were made of. The search focused on a substance called deoxyribonucleic acid, now known colloquially as DNA, which is found present in the nuclei of all cells. It became necessary to find out just how DNA was made and how it could transmit the message of heredity from generation to generation. One of the outstanding landmarks in this field was the finding by three scientists at the Rockefeller Institute that acquired characteristics could be transmitted in a hereditary manner. This caused the overthrow of one of the concepts of genetics but at the same time it strengthened our understanding of the field. These three scientists, Avery, Macleod and McCarty, found that DNA from one strain of bacteria could enter the cells of another strain and transform it. The transformed characteristics were passed from then on from generation to generation. In 1953 it was found by Watson and Crick just how the DNA molecule was put together and how this one molecule could carry all the information for all forms of life from generation to generation starting with the very origin of life itself.

I must get technical to show you just how this takes place, and it is done by a phenomenon called hydrogen bonding. This takes place between two components of DNA, such as guanine and cytosine. DNA is built like a twisted ladder. Figure 1 shows how long chains of phosphate sugar molecules

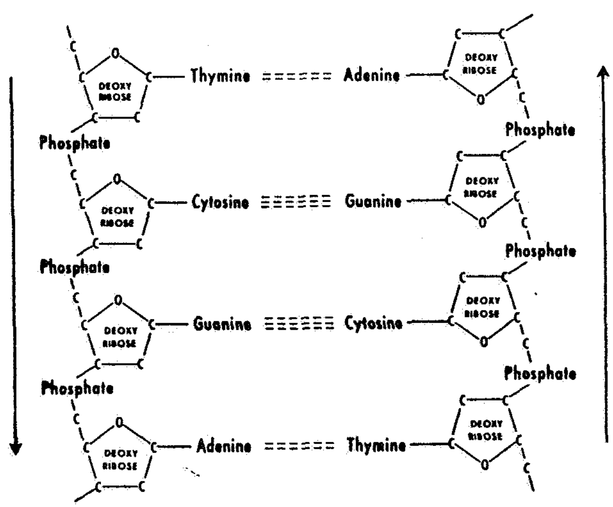


FIG. 1. ***Structure of part of a DNA molecule. Dotted lines indicate hydrogen bonds that hold the two chains together.***

form the vertical uprights of the ladder. The rungs of the ladder are formed by the cross pieces. In one of the two types of rungs guanine is always linked with cytosine by three hydrogen bonds. The cytosine or C may be on the right or left side in which case the guanine or G will be on the other side. The other pair is shown in Figure 2; this is the pair formed by adenine and thymine with two hydrogen bonds joining them.

The genetic message is constructed in the same manner as a language. Each long sequence consists of a permutation, of a few different units, and this is continued for millions and millions of letters, selected from the DNA alphabet of A, G, C, and T. The other half of the molecule contains the other half of the component. Here was the solution of the riddle; of the code of life; of how the message of heredity was passed from generation to generation. One of the many fascinating things about this concept was that it simulated the process that human beings use in putting a language together. DNA consists of linear permutations of variable units just as a language does. These are broken apart into words by spacing and by means of this system there is enough variability to account for every different species of living organism on the earth and far more. The number of permutations that can be written with the four variables in DNA is--even for a short molecule of DNA--greater than the number of elementary particles in the entire universe. The effect that this produced on biologists was, I think, somewhat akin to a quotation I read recently by an African who was talking about the impact of modern learning on his life, and I quote:

> He said, "The one crowded space in Father Perry's house was his bookshelves. I gradually came to understand that the marks on the pages were trapped words. Anyone could learn to decipher the symbols and turn the trapped words loose again into speech. The ink of the print trapped the thoughts. They could no more get away than a doombu could get out of a pit. When the full realization of what this meant flooded over me, I experienced the same thrill and amazement as when I had my first glimpse of the bright lights of Konakre. I shivered with the intensity of my desire to learn to do this wondrous thing myself."

The task that confronted biologists was to translate this long permutation of variables into protoplasm, present in living organisms. Workers in the biological sciences have found out the track, so to speak, of the formula of DNA, and from then on it was a question of making predictions and testing them. This was a procedure which was somewhat foreign to the manner in which the biological sciences had previously been travelling, and a procedure which many of the older biologists resisted and still resist. For example, just recently, two months ago I was accused in print of deifying a molecule.

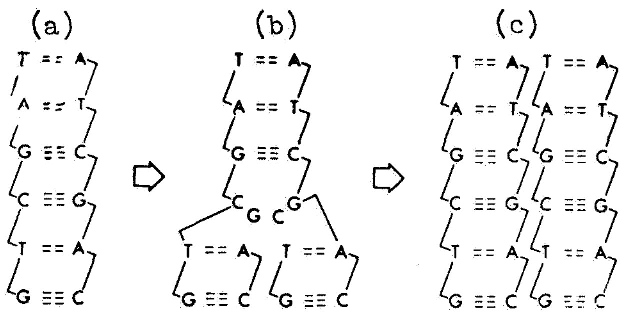


FIG. 2. *Method of formation of two double strands of DNA (c) from a parent double strand (a). In (b), the complementary Watson-Crick pairing that accompanies the replicating procedure is in progress.*

Figure 2 shows one of the great concepts of biology: how one DNA molecule--here shown as just a short segment of it--can produce two, each of which is identical with the parent. This is by separation of the strands one base pair at a time and by insertion of new complementary bases. As this procedure goies along, like a zipper, it leads to the formation of two identical molecules. This is the way in which cells multiply, and in which information gets from parent to offspring. So far, just as in the quotation I read to you, the information is trapped as it is trapped in books. What we need to find out next is how it is transcribed and translated into living organisms.

We saw in Figure 2 that the trapped information has duplicated to form two molecules, but there is a second analogous process that goes on all the time. This is illustrated in Figure 3. Here is the same piece of DNA that you saw

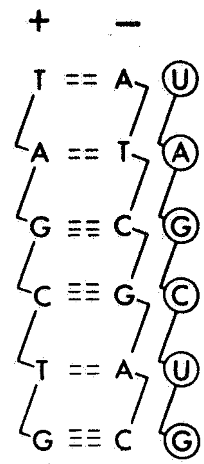


FIG. 3. *Formation of RNA (. . . UAGCUG . . .) by modified complementation with one strand of DNA.*

before, but this time it is forming another similar molecule with only one strand. This is a molecule of RNA. It differs from DNA in that it contains uracil instead of thymine, and there is a different sugar in RNA so it is a slightly different molecule, although with many similar properties; but, the one thing that is outstandingly different is the fact that it is single-stranded rather than double-stranded.

There are three main types of RNA molecules, and the difference between them is solely due to the number and kind and sequence of bases in each. They have three separate functions, all of which are connected with manufacturing living organisms from instructions that were in the original DNA molecule. The first and most versatile type of RNA molecule are the so-called messenger RNA and here the trapped information truly comes to life--the medium is indeed the message. Messenger RNA is read off in successive groups of three bases, each of which specifies an amino acid. The mechanism for doing this is quite complex and excites our admiration.

It is done by means of another family of molecules called transfer RNA. Each molecule of transfer RNA picks up an amino acid and finds its place on the message, again matching itself up so that U pairs with A, A pairs with U, C with G, and G with C. This procedure guides the amino acids into place and they join together to form proteins. Aggregations of proteins are directly responsible for all the properties we associate with life including structure, function, metabolism, growth, and the control of our body reactions, and so on.

Table 1 shows a list of the twenty amino acids that are concerned in the synthesis of protein. Here we encounter something that again has a counterpart in philology. We go from one language to another. We go from a

TABLE 1 Amino acids that take part in protein synthesis and their abbreviations

AMINO ACID	ABBREVIATION
Alanine	ala
Arginine	arg
Asparagine	asN
Aspartic acid	asp
Cysteine	cys
Glutamic acid	glu
Glutamine	glN
Glycine	gly
Histidine	his
Isoleucine	ilu
Leucine	leu
Lysine	lys
Methionine	met
Phenylalanine	phe
Proline	pro
Serine	ser
Threonine	thr
Tryptophan	try
Tyrosine	tyr
Valine	val

language which contains four letters to a language which contains twenty letters, and we have to do this every time a genetic message is translated into a living organism. The long permutation of four units is changed into one of 20 units. The properties of the amino acids are so varied and versatile that they can give rise to all the differences that one sees out of this window in the living organisms that surround us: the insects, shrubs, flowers, and bluejays of Strawberry Canyon.

The next question that confronted biological scientists was how this translation takes place. What does one base mean? What do three bases mean in terms of amino acids? The solving of this riddle took place within the past two or three years, and it is called the genetic code. The genetic code refers to the translation procedure by which the four-letter language of DNA is translated into the twenty-letter language of the proteins.

Table 2 The Amino Acid Code

UUU Phe	CUU Leu	AUU Ile	GUU Val
UUC "	CUC "	AUC "	GUC "
UUA Leu	CUA "	AUA "	GUA "
UUG "	CUG "	AUG Met	GUG "
UCU Ser	CCU Pro	ACU Thr	GCU Ala
UCC "	CCC "	ACC "	GCC "
UCA "	CCA "	ACA "	GCA "
UCG "	CCG "	ACG "	GCG "
UAU Tyr	CAU His	AAU Asn	GAU Asp
UAC "	CAC "	AAC "	GAC "
UAA Chain Termn.	CAA Gln	AAA Lys	GAA Glu
UAG " "	CAG "	AAG "	GAG "
UGU Cys	CGU Arg	AGU Ser	GGU Gly
UGC "	CGC "	AGC "	GGC "
UGA Not translated	CGA "	AGA Arg	GGA "
UGG Trp	CGG "	AGG "	GGG "

Table 2 shows the 64 possible 3-base permutations, called codons, of the bases adenine, cytosine, guanine, and uracil (A, C, G and U). Any four variables can be arranged into 64 permutations taken three at a time. Each codon has a biological function. In various cases, an amino acid is specified by four, three or two codons. There are two amino acids that are specified by only one, and, finally, three are set aside for saying: stop one protein and start another. The genetic code is the key that helps us understand the exact relationship between nucleic acids and proteins.

What happens when the code is translated? Obviously, it is a situation of great complexity. First of all, each cell in our bodies contains the complete information to make another human being if the sequence of bases in its DNA is translated. Of course, it is only the sex cells that are involved with the function but nevertheless the information is within the DNA contained in each cell. And, the DNA contained in each of our cells contains about three billion of the base pairs that I have illustrated. Not all of them are used--only a small fraction of them are used. The length of the DNA molecules in our bodies, in one human body, if placed end to end would reach far beyond the moon, so this is a very long and thin molecule--and it is rather difficult for us to understand how it can be compressed into a unit so small as a cell. This takes place because it is so long and thin and because it is compressed and packed by being twisted and turned. In a nutshell this is the way in which hereditary information is transmitted. When we think about this phenomenon, we realize the impact that it produces on many of our biological concepts, and the one which I think is most interesting and which I want to talk about a bit is the concept of evolution. It has been apparent for a long time that evolution must take place by some continuity which bridges the gap between each generation. Evolution is therefore a branch of genetics. Genetics is concerned principally with information being transmitted repeatedly, but evolution is concerned primarily with the changes that can take place in the hereditary information. For a long time the question of such changes was very obscure, and it was not until work in plant breeding showed the existence of what are called mutations that some light began to be cast on it. Mutations are changes that take place in DNA molecules, and some of these changes--but not all of them--produce differences in the offspring. The discoverers of the formula of DNA, Watson and Crick, immediately pointed out how mutations could occur on the basis of the molecule of DNA. They proposed that when this molecule was being duplicated a mistake was occasionally made. Suppose that a C was replaced by a G. Then, the next time that this strand of DNA was duplicated, there would be a C on the opposite side. As a result, the UAC could be replaced by UAG. This would be a very significant mutation. It is called an amber mutation, and it produces the termination of a protein molecule. It is called amber because it was discovered by a graduate student at the California Institute of Technology named Bernstein. The story is that two of his classmates promised to name some mutants for him if he would spend the evening working with them in the lab rather than going to the movies. The amber mutation brings about a split in the protein molecule and you can see that this might have serious consequences by causing the loss of an essential protein.

Another and more familiar example of a mutation caused by a single-base change is the mutation that causes sickle-cell anemia. In the molecule of hemoglobin, if the sixth amino acid from the end is changed, then the hemoglobin changes its properties--it ties itself in knots in the blood cells, and they do not transport oxygen normally and so the unfortunate possessor of this mutation becomes anemic. Strangely enough, these anemic blood cells also resist the action of the malaria parasite, so although the sufferer is anemic he also resists malaria. This has led to the perpetuation of this otherwise deleterious mutation, and, therefore, has had an effect on evolution. So, here we see in a thumbnail sketch how a single-base change can affect evolution.

The next slide shows a quotation from the Tennessee statutes.

> "It shall be unlawful for any teacher in any of the universities, normals and all other public schools of the state, which are supported in whole or in part by the public school funds of the

state, to teach any theory that denies the story of the divine creation of man as taught in the bible, and to teach instead that man has descended from a lower order of animals."

Tennessee Statutes, 1925

I like to show this slide when I am talking in the South because I believe this law is still on the books, and since this law was passed we have gone on to a different concept of evolution, and it is difficult to take issue in the same way. I spoke of the contributions of a man of the cloth, Gregor Mendel, who founded genetics. There was also a cleric who engaged in a debate on evolution. This was Bishop Wilberforce who attacked the concept that human beings could be related to the apes; and he asked his opponent whether he was descended from the apes on his mother's or his father's side of the family. The famous retort to him was made by Thomas Henry Huxley, who said that in effect he would rather be descended from an ape than to be of the same family as Bishop Wilberforce. The excitement generated by the debate was such that a lady in the audience fainted.

The molecule of DNA gives us a plan for a new approach to evolution. In any molecule of DNA, the mutations which I mentioned take place at irregular intervals because there is a very small percentage of mistakes made inevitably when a DNA molecule is copied. If there is a random distribution of hits along a DNA molecule, we can study the result in various mathematical ways by means of theorems such as the Poisson equation.

The proposal can be examined by analyzing protein molecules, which are long sequences of amino acids, and we can compare analogous protein molecules in different species. For example, the hemoglobin from human beings can be compared with hemoglobin from horses, and there are about seventeen of these changes scattered over a distance of 146 amino acids.

If, instead of human beings, the hemoglobin selected for comparison with that of the horse is that of a sheep, then a quantitatively similar comparison appears, but there is a different pattern of scattering of the changes along the molecule.

Molecular evolution is a science that is just in its infancy. It has been pursued a considerable distance in the case of a protein called <u>cytochrome</u>. This is a very widely-distributed protein. It contains about 102 to 109 amino acids and it varies from species to species. There is only one amino acid difference between human cytochrome and that of the monkey, but there are 13 differences between human and chicken cytochrome and 40 differences between human and wheat cytochromes. The cytochromes extend over a large range of species than do the hemoglobins.

Table 3 summarizes some of this information.

Table 3

Percentage Differences in Cytochrome Molecules

	Man	Horse	Chick	Tuna	Moth
Man					
Horse	13				
Chicken	15	13			
Tuna Fish	30	24	27		
Moth	34	31	30	38	
Bread Mold	57	59	58	67	58

As we get further and further along what is called in biology the phylogenetic tree, the separation is mirrored very closely in the differences between the cytochrome molecules. There is a 57% difference between the <u>cytochrome C</u>

in human beings and that present in the common bread mold. It is not only the 57% difference that is of great interest, but it is the 43% of identity, because this high percentage of identity is far too great to explain by chance, and so the odds are many millions to one that we are descended from the same original living organism as the bread mold. Not only does this apply to human beings, but it applies to the different species *inter alia*, so we can construct a phylogenetic tree, a tree showing all the descent of all living species, carrying cytochrome molecules from the same original archetype, the same primordial life.

Evolution is placed on a very impersonal basis by using proteins as a model, translating them back into terms of DNA, and using the concept that DNA is responsible for the transmission of hereditary characteristics. Obviously, there are other differences between ourselves and the more primitive organisms that have a much more restricted function. This again is mirrored in the nature of the DNA molecule. Our DNA molecules are much longer than those of single-celled organisms. They are about 500 times as long as those in the bacteria *E. coli*, and they are about 1500 times as long as those in the bacterial virus known as T2. However, lest we become puffed up, there are organisms which contain more DNA in their cells than we do--including salamanders. This, we presume, is because they have a greater reserve of unused DNA. Part of evolution reflects the single-base mutation changes in DNA, but obviously there is another component that must be taken into account and that is lengthening of DNA as we go from the more primitive organism to more complex ones. This shows you a section of the DNA contents of a cell. When reduction division takes place, the number of chromosomes is halved by meiosis; then, there is pairing and sometimes there is unequal crossing over so that one of the two daughter cells has a chromosome that is perhaps 25% longer than its progenitor, and the other cell has a chromosome that is 25% shorter in length. Now, here you see this new cell will have two red sections. One of the sections of the longer chromosome will be used for its original purpose, perhaps for the coding of a hemoglobin molecule, while the added piece of DNA is a spare. The spare in the process of evolution can undergo mutations and become differentiated so that it produces a new protein and the organism becomes more complex. This is actually what has happened four or five times in the evolution of hemoglobin so that as compared with a primitive species such as the lamprey, human beings have a more complex type of hemoglobin made of several units.

The next slide shows how I have tried to impress upon some of my students the connection between the ideas of a poet and a response which is provided by biology (see page 14). Here, in the poem, Blake wonders how the tiger could have reached its predatory and ferocious character, and our answer to this is a mnemonic poem which states that the formation of the tiger takes place by means of the four bases that are in DNA and the twenty amino acids that are present in proteins. The responses all scan and they all rhyme, but I doubt very much whether it will ever be a popular modification of Blake's poem.

Molecular biology serves to unify the study of life, evolution, and the components of which living organisms are made. The nucleic acids and the proteins have properties that are inherently due to the elements which they contain. These elements are a part of the family of elements that is found throughout the universe, and so we presume that there is a basis for

Tiger, tiger, burning bright
In the forests of the night,
What immortal hand or eye
Could frame thy fearful symmetry?

Guanine, thymine, A and C!

In what distant deeps or skies
Burnt the fire of thine eyes?
On what wings dare he aspire?
What the hand dare seize the fire?

AsN, lys, pro, his and tyr!

What the hammer? What the chain?
In what furnace was thy brain?
What the anvil? What dread grasp
Dare its deadly terrors clasp?

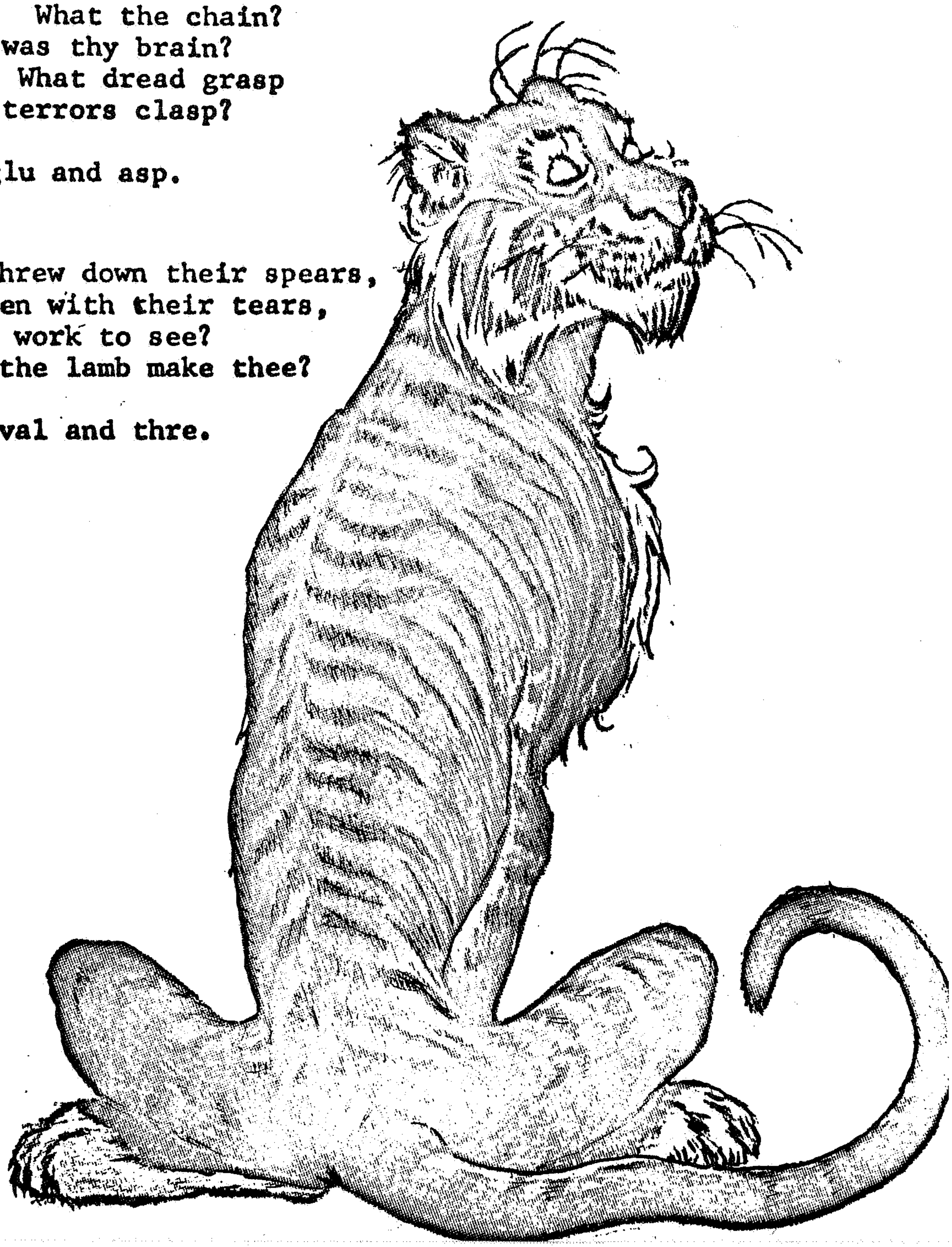
Ala, leu, try, glu and asp.

When the stars threw down their spears,
And water'd heaven with their tears,
Did He smile His work to see?
Did He who made the lamb make thee?

GluN, met, arg, val and thre.

Tiger, tiger, burning bright
In the forests of the night,
What immortal hand or eye
Dare frame thy fearful symmetry

Ser, cys, ileu; phe and gly!



the origin and evolution of life in worlds other than our own. I do not have a quotation to bring this point home because perhaps this information is too recent, but I would like to conclude with a verse written about a hundred years ago which is relevant to the contemplation of the universe and perhaps also has its application to the unified framework of biology:

> Soaring through wider zones that pricked his scars
> With memory of the old revolt from Awe,
> He reached a middle height, and at the stars,
> Which are the brain of heaven, he looked, and sank.
> Around the ancient track marched, rank on rank,
> The army of unalterable law.

The study of molecular biology prompts us to contemplate the unification of cosmology from the very large to the very small, brought about by the laws of physics and chemistry that provide a unification in our viewpoint towards our environment.

SOCIAL SIGNIFICANCE OF TECHNOLOGICAL ADVANCE*

Ida R. Hoos

Introduction

Science and technology are morally neutral; they have their own standards, their own goals. Perhaps their purpose, as Robert Hooke said of the design of the British Royal Society in 1663, should be "to improve the knowledge of naturall things, and all useful Arts, Manufactures, Mechanick practices, Engynes and Inventions by Experiments--(not meddling with Divinity, Metaphysics, Moralls, Politicks, Grammar or Logick)." But in the past three centuries, compartmentalization has become increasingly difficult. As more and more matters move from the realm of the unknowable to the unknown and then to the known, they make their impact felt on every living being. Perhaps "Divinity" and "Grammar" may not be too much involved, but "Metaphysics," "Moralls," and "Politicks" certainly are! Consequently, the effects of science and technology must be considered in terms which are unequivocally normative. The uses and abuses, direct and indirect, overt and hidden, are ethical issues, and whether the outcome is beneficial or detrimental to mankind must be assessed with reference to the human and social values at stake.

With every scientific breakthrough, there are new and wondrous possibilities; with every technological development, there is promise. But there are also new responsibilities and dangers. From the discovery of fire and the invention of the wheel to the smashing of the atom and the

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*Paper based on talk given at Annual Conference of Episcopal Cathedral Deans, Berkeley, California, April 7, 1967.

exploration of outer space, man has opened new vistas, but these advances do not necessarily deserve to be categorized as progress. What may appear as a spectacular breakthrough may generate more problems than it solves. Frequently, a scientific or technological development has high, wide, and hidden human and social costs. While still on the threshhold of the Space Age, we humans sense that the breadth and pace of change are creating difficulties because our natural and social systems are incapable of such rapid adjustment. Man has remained pretty much the same creature since the Stone Age, but just look at science and technology!

The second half of the twentieth century has many appellations; the past decade and a half has given legitimacy to such labels as "Scientific Society," "Space Age," and "Technological Revolution." While all of them are appropriate to our time and relevant to our interest, I should like to select the third, i.e. "Technological Revolution," as the leitmotif which best connotes the dynamic and the tempo of contemporary civilization. My research into the social implications of technological change is sponsored by the Space Sciences Laboratory of the University of California under a grant from the National Aeronautics and Space Administration. This agency makes explicit its concern that the public derive maximum benefit from its endeavors and that universities accept a responsible role in them. Significantly, the mandate is interpreted broadly so as to encompass not only the processes and mechanisms for technology transfer and utilization but also the wider sociological significance of the technological revolution.

The Computer and the Imperative of Quantification

In a thoughtful and thought-provoking book, the nuclear physicist, Ralph E. Lapp, made the statement that technological possibilities are irresistible to man.[1] An invention or discovery, once made, takes on a kind of imperative of its own and will be put to use. The computer is a prime example of this phenomenon. Not only has it been put to use, but it has widened its sphere of utilization to penetrate into practically every facet of our lives. This leads us to a corollary to Dr. Lapp's dictum, viz., that each invention creates and furthers its own demand. Once an accessory for the mighty few, the computer soon became a common necessity. Now, no self-respecting business firm or government agency could function without it. The computer is not only the symbol of the technological revolution but a powerful determinant of its pace and direction. In 1955, when the first commercial installations of electronic data-processing equipment became operative, computers were a sort of mechanical monster, very large and very expensive. They were regarded as automated bookkeepers and assigned almost exclusively to routine accounting procedures. In the decade or so that has elapsed, the amount of computing power has grown spectacularly while at the same time micro-miniaturization has led to vest-pocket or under-the-dashboard sizes. When we talk in terms of "order of magnitude," we mean a change by a factor of ten. Experts tell us that computers have improved in speed by at least seven orders of magnitude over hand calculations; this is a 10 million-fold increase. At the same time, the decrease in the cost of operation has been four orders of magnitude, or more than 10 thousand times cheaper. The prediction has been made that 1975 will compare with the precomputer era by 10 to 12 orders of magnitude in speed (or a thousand billion) and by 6 to 8 orders in cost.[2] Small wonder that among computer

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[1] Ralph E. Lapp, The New Priesthood, New York, Harper and Row Publishers, 1965, p. 67.

[2] Paul Armer, "Computer Aspects of Technological Change, Automation, and Economic Progress," report prepared for National Commission on Technology, Automation, and Economic Progress, September, 1965, p. 67.

designers there is the axiom, "If it works, it's obsolete!"

Because of their phenomenal speed, computers long ago passed beyond the stage of mere commercial accounting. New areas of application proliferate as hardware concepts undergo improvement and software (i.e., programming) becomes more sophisticated. No longer the passive instrument for churning out bills and financial reports, the computer now occupies a central role in vital decisions impinging on ever-growing areas of our lives. To an extent that few of us yet appreciate, everything and everyone is being turned into data for a computer to process for one purpose or another. Dollars and cents used to be the sole legitimate business of the computer, but with increasing reliance on quantitative techniques for social planning, people and ideas now are regarded as appropriate input. I might observe parenthetically that despite the considerable drop in costs of computer operation they are still substantial, and that zeal to make use of every available second has resulted in the gathering, storing, collating, and retrieval of vast amounts of data, as well as an enormous proliferation of reports.

The computer has become the instrument central to program development and budgeting in practically every department of the federal government as well as many at the state and local levels. Reliance upon it is so great, in fact, that the very problems to which society will turn a hand must be framed in quantitative terms amenable to electronichandling! For example, the systems approach, which was developed to a high degree of sophistication in defense and aerospace activities, has entered the arena of public affairs and is providing enormous impetus to the trend toward omni-computerization. The drawbacks of undue dependence on quantification are obvious; the dangerous impacts have yet to be fully experienced. But it already appears that the very factors which contribute to and exacerbate a particular social problem could be overlooked, ignored, or omitted because they defy programming; they could persist and fester while society is lulled by the false security of a "scientific" solution. If one were to "analogize," which is not only acceptable but actually recommended in this methodology, one might say that the present view of the social system has the computer as its heart, data-flow its bloodstream, and the program its intellect! Russel Baker, in a satirical column in the New York Times,[3] proposed a new pledge of allegiance for late twentieth century man: "I pledge allegiance to the computer and to the machine for which it stands; one organization, under IBM, inescapable, with punch cards and dossiers on all."

The Nameless, Faceless Society

Before the days of the *toto reductio ad datum*, Emily Post was the arbiter of social nicety, and the engraved calling card a symbol of gentility. Nowadays, technical efficiency dominates our cultural mores; the punch card is our mark of identity. One's name is useless in electronic data handling. It is only one's numbers that count. And the various numbers that have come to stand for us expedite the preparation of our bills and bank statements, the issuance of our automobile registration and traffic violations, the calculation of our paycheck and tax assessments. Performance of any of these systems in which we are the inputs is based on speed. But the more powerful the computers the more data they hunger to digest. The result is not reduction of paper flow but actually a proliferation of such proportions that the technological revolution has given rise to a serious data explosion. Note that in the process man has

[3]Russel Baker, "Observer: The American Papers," New York Times, April 13, 1967.

ceased to be the end to be served by the given system and has instead become a sub-unit to be programmed.

The cult of technical efficiency which predominates in our society has its own priests, who probably have a high IQ but who may be lacking in EQ (Ethical Quotient).[4] Indeed, the contemporary preoccupation with techniques has caused concern among theologians lest men who may be specialists in their own fields but lacking in ethical wisdom and commitment, be entrusted with vital decisions affecting all mankind now and in the future. A conference on the Role of Conscience has been slated for early May, 1967, under sponsorship of the National Council of Churches, the Committee on Inter-Religious Affairs of the National Conference of Catholic Bishops, and the Synagogue Council of America. Funded by a Ford Foundation grant, this interfaith colloquium is an expression of the growing recognition that basic human values are being threatened as worship of the golem, technical efficiency, becomes more pervasive.

Whatever our age, stage, or status, the primary impact of the computer is on our attitudes toward and sense and use of time. Even in the educational system, which has a tradition of resistance to innovation, curriculum and class arrangement by computer is gaining ready acceptance. Secondary schools throughout the United States and several in Japan have adopted a technique called "flexible scheduling," developed by Stanford University. This may be the well-intentioned objective, but in practice, programming this function creates the opposite effect. The school's entire operation gets cast in the time sequence the computer requires, and exceptions due to individual problems and emergencies are intolerable. Teachers and counselors, under pressure to deliver to the system the

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[4]Dennis Gabor, "Fighting Existential Nausea," Technology and Human Values, Santa Barbara, California, Center for the Study of Democratic Institutions, September, 1966, p. 15.

information it demands and in the precise form it requires, complain that they have less time than ever before for personal contact with the youngsters. Group counseling sessions, utilizing closed-circuit television, have been proposed as a remedy! In our local high school, honor society members used to look forward with special eagerness to their senior year, for, as a reward for past performance, they could specify teacher preference in one course. Now, thanks to the computerized system, this privilege has been withdrawn; exceptions are too time-consuming and costly.

In by-gone B.C. (Before Computer) days, the report card served as a communication link between school and home. Parents were required to sign it, and the "Remarks" column afforded opportunity for some dialogue. At semester's end, the card represented an interesting cumulative summary, a memento of the tutelage of Miss Lizzie T. Higgins or Mrs. Kate F. Holbrook, who wrote their names with Palmer methodical precision at every grading period. The parental signature was no perfunctory matter either. Throughout my school days, report-card signing was a special kind of ceremony, the occasion for exhortation and the distribution of rewards. Even when I was a studious senior on the Dean's List at Radcliffe, my father stuck to his policy of "a dollar for every A," despite deep Depression. By contrast, the report card of today is a machined print-out. Like a soda pop bottle, it is one-way and non-returnable. Whatever comments the teacher may make appear in coded form. For example, the numeral 5 means "assignments not turned in and/or properly prepared"; 8 means "misconduct and/or poor attitude." Parents' responses are neither invited nor expected. The system simply does not provide for them. Paradoxically, while this improvement of pupil-processing efficiency increases, school administrators are seeking avenues to overcome parents' apathy and lack of involvement in the education of their children.

As might well be expected, technology has not taken a back seat in the classroom, either. In the guise of objective tests, the true-false or cafeteria format that can be scored mechanically, it entered the picture long ago. If we wonder why Johnny never learned to express himself in writing, we might find it worthwhile to ask him to respond to the following: "My teachers had the class write essays. (Check one) Frequently . . . Sometimes . . . Never . . ." Teaching machines and programmed instruction were the next logical step, and their uses have been explored at every grade level from kindergarten to college. Perhaps to demonstrate the flexibility of such techniques, some experiments were conducted on speeds of presentation and learning of materials. Taped materials were flashed onto screens or played for hearing at various rates, and the subjects were tested to see how fast they could respond to the respective media. Whatever the results of these particular tests, I doubt that humans can absorb at a pace anywhere near the capability of transmission of information: Telstar sent data across the Atlantic at the rate of 1.46 million words per minute, fast enough to send the entire works of Shakespeare in 25 seconds and the full King James version of the Bible in 45 seconds. Perhaps this lag between human and electronic brain need not concern us unduly: the incoming impulses can be stored in the computer's memory, where they will remain unless called for! Actually, this is a serious matter, for "educational technology" may be violating basic psychological principles of learning. Professor Gordon W. Allport[5] reports that he asked 250 college students to write down three vivid memories of their eighth grade school work and to indicate the kind and degree of their own

[5]Gordon W. Allport, Personality and Social Encounter, Boston, Beacon Press, 1960, p. 185.

active participation in the recorded events. For example, were they reciting, playing, arguing, producing, talking; or were they listening or watching passively without overt involvement? He found that three-quarters of the memories were for situations in which the subject himself was actively participating.

There are other drawbacks to automation in education: Canned pedagogy could stifle imagination on the part of teachers. In the hands of unprogressive, economy-minded school administrators, programs would be used beyond their period of applicability. Thus, course content would become frozen, static, and anachronistic. Altogether too often, a selection of educational packages is done by less than adequately equipped persons, for whom political considerations or smooth sales talk bear more weight than they should. If such individuals are unfamiliar with what constitutes the appropriate materials for a given school grade and the optimal techniques for making them meaningful, the result could be an institutionalization of ineptness far exceeding one poor teacher or textbook in potential for damage.

Communication technology has made quantum leaps from the days of Marconi and the Morse Code. In Daniel Bell's words, "Whatever else may be said about the 20th century, it has produced the greatest bombardment of aural and visual materials that man has ever experienced in his history."[6] And one cannot but ask whether man has the physical and emotional stamina to cope intelligently with the barrage of stimuli that assail his senses at every turn. The mass media present news of riots in Hongkong, death in Vietnam, and upheaval in the Middle East, with the same intensity as reports of traffic on local freeways and exhortations to smoke

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[6] Daniel Bell, "Notes on the Post-Industrial Society," The Public Interest, No. 7, Spring, 1967, p. 110.

longer cigarettes. The resultant sensory overload has contributed to a serious inability to react appropriately; it has also led to a marked tendency to trivialization. An example of this may be drawn from reports of space exploits: The world marveled when Shepard made his suborbital flight; they followed every movement of Glenn's orbit. When Carpenter missed his splashdown point and was out of contact for an hour, people in Grand Central Station fell to their knees <u>en masse</u> and prayed. But when a very serious emergency occurred during the Gemini 8 flight (Spring, 1966), the switchboards of the television affiliates of the American Broadcasting Company were flooded with calls from Batman enthusiasts protesting the pre-emption of this program. The process of trivialization, as illustrated here, is not always so easily discerned; it more often converts the unthinkable to the commonplace. Thus, World War III, total destruction, and bone-chilling inhumanity of man against man are all intruded into the viewer's or listener's mind so frequently as to become matter-of-fact.

Psychologists have for decades been concerned with the impact of the mass media on man and his society. Lonely in the crowd, the creature of mass society is likely to become even more alienated as he retreats before the assault of electronic stimuli. "Batman" serves as an escape hatch for only certain types of personality. For many others, the self-defense mechanism takes the form of psychological withdrawal, a mode of behavior ordinarily encountered in situations where the individual is under great stress from external pressures. Under such circumstances, a kind of encapsulation or cocooning has been observed to occur. Those of us who do not find a haven in "Batman" may emulate Charlie Brown's friend, Linus, with his security blanket!

It is clear that we have become a nation of spectators. As such, we may be in greater danger of succumbing unconsciously to manipulation than we realize. Commercially-inspired suggestion has already proved itself in the marketplace, as witness the nationwide sales record of a 12 dollar toy called "Thing-Maker with Creeple People," advertised on network children's programs. An old phenomenon in this country, consumer preference formulation via television has, according to Tadashi Okuyama, the publisher of Japan's TV Guide, almost completely eradicated century-old inter-regional and urban-rural differences in clothing styles. Tokyo standards have also made their imprint on speech patterns throughout the land. Image-making, the specialty of the public relations profession, has moved from the sphere of soap into such areas of vital concern as politics and education. The results of certain election campaigns indicate the possibility that voters tend unconsciously to judge the candidate by the standards of the medium. It has been conjectured that Richard Nixon was defeated by his own five-o'clock shadow; perhaps the casting of Ronald Reagan as a hero won him a governorship. In Japan, television is credited with having produced a winning candidate, Mrs. Aki Fujiwara, for the House of Councilors; she had established a national reputation through her appearances on the Japanese equivalent of the American "What's My Line?" panel show.

"Brainwashing," an activity generally attributed to sinister undercover agencies and malevolent subversives, has ugly connotations; it implies the deliberate suppression of intelligent, conscious thought processes. Educational technology, with its closed television circuitry, computers, and prepackaged programs, does not deliberately suppress conscious thought; it simply by-passes it. Telecommunications make it possible for the student to sit at home and receive his instruction by simply dialing into the television set. Lessons, drill sessions, and entire plays and concerts will be available at the touch of a button. His interaction will, however, be largely with the machine and the packaged program and not with a teacher and other students. The purpose of these changes is to improve the efficiency of the educational process. Experimentation suggests, however, that it may have deleterious consequences.

In Australia, some three hundred 13-year-old children from five schools were subjected to programmed instruction about a fictitious race called the "Javas". Through it, the youngsters were indoctrinated with notions about how different these people were from Australians, that they wore veils to hide their faces, slept during the day and moved stealthily about at night, that they ate the flesh of young calves after cutting their throats and allowing the blood to drain out. Dr. Maurice Balson, senior lecturer in education at Monash University, Melbourne, reported that the children, when tested, indicated fear and hatred of these imaginary neighbors. Putting aside for the present the very necessary question that should be raised about such tampering with attitudes, even in the name of scientific investigation, one can understand that the results were taken as a warning of what could be done to people's minds through an "educational" technique which encourages learning without the development of critical thought. Dr. Balson pointed out the obvious dangers of misuse by advertisers, and, even more important, possible exploitation and manipulation by powerful factions in government to swing the opinion of whole populations on vital issues.

The "programs," or instructions, need not be confined within the machine. Technology has advanced to such a point that there can be a linkage of microminiaturization and this kind of educational process. The digital differential analyzer, developed a year ago, had as a subsystem a high-speed, special purpose computer on a chip of silicon 86 one-thousandths of an inch by 72 one-thousandths. Frequency modulation transmitters in the form of thread-like catheters have been placed in the blood stream of animal subjects for monitoring the functioning of vital organs. With advances in bio-engineering, all kinds of sophisticated biotelemetry are possible. At the Yale Medical School, Professor Jose M. R. Delgado has conducted a great deal of widely-publicized experimentation on the use of tiny electrodes implanted directly in the subject's brain. He was able by remote suggestion to stop a charging bull in its tracks and cause it to trot away quietly. Recently, he succeeded in making a female monkey reject her own offspring on radio command. At a scientific meeting, he told colleagues that experiments with patients suffering from epilepsy or emotional illness "seem to support the distasteful conclusion that motion, emotion, and behavior can be directed by electrical forces and that humans can be controlled like robots by push-buttons."[7] That education, once regarded by psychologists as an antidote to the mob mind, could become the vehicle for the "conditioning" of the younger generation, forces one to realize that 1984 is closer than we think!

In their zeal to hasten the educational process by electronics, technology enthusiasts overlook or ignore not only such basic factors in the learning process as motivation and maturation but also the benefits to be derived from a group experience. The support and stimulation are far more meaningful in the long run than all the screened and canned culture that programmed tele-education can ever produce. Without opportunities for interaction with teachers and other students, our young

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[7]As quoted in editorial, "Push-Button People?" New York Times, January 10, 1967.

people may suffer even greater alienation than is already apparent on college campuses. Dr. Seymour L. Halleck, director of student psychiatry at the University of Wisconsin, presented a sobering account of this growing problem when he addressed the 1967 meeting of the American Psychiatric Association: Bored, apathetic, and unhappy, the alienated student suffers from a chronic identity crisis, and turns to marijuana, LSD, or even suicide. Dr. Halleck's prescription, more genuine contacts with adults, suggests that automation not only does not have all the solutions to modern educational problems but may even be a contributing cause of them!

Coin Box Morality and the Anomic Society

Those of us who still cling to the old-fashioned notion that we humans are masters of our existence need only recall the reproving glance of the clerk at the telephone office when we pay our bill without returning the punched card that came with it. And who among us is so free, so brave, and rich as to defy the injunction not to bend, fold, or staple our own paycheck? A civilization in which so many facets of life are defined by the idiosyncracies of the computer's digestive system is likely to nurture something best described as a "coin box morality". The telephone booth ethic which justifies pocketing the erroneously returned dime in return for the many which have been irretrievably lost to its arbitrary and vexatious functioning now encompasses many and broad areas of human experience.

By way of proof, the Investigation Commissioner of the City of New York recently reported a substantial increase in the incidence of slugs in parking meters.[8] In 1962, there was one slug among every 537 dimes collected; in 1967, the ratio changed to one to 38, a 15-fold

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[8] Sylvan Fox, "Fraiman Reports Meter-Slug Rise," New York Times, April 12, 1967.

increase. Statistically unimportant but nonetheless telling was a personal experience in Naples, Italy, where many of the apartment buildings are equipped with automatic elevators which run only when a 10-lire piece is inserted in the slot. At the weekly meetings of the Girl Scouts in her apartment, the American leader, whose husband was an officer in the U.S. Mediterranean Fleet, thoughtfully lent the youngsters the "dieci" (10-lire piece) pierced through the middle and tied onto a string, her family's permanent pass to free vertical transport. Honest souls who would never deliberately cheat another human regard the machine as their natural enemy and gleefully take advantage of its errors, aberrations, and vagaries. Even the most scrupulous student does not report the extra point that he receives when the automatic sensor misreads a <u>true</u> - <u>false</u> mark. Similarly, as radar clocks our car speed and the computer checks our work performance, the undetected slip becomes the credit item in the constant skirmish between the human being and the impersonal forces impinging upon him. Beating the machine may become a recognized game in society just as it is in computer laboratories, with honor and ethics simply not written into the rules.

The coin box morality that guides behavior in the telephone booth and at the curbside prevails wherever the individual interacts with a depersonalized system. Honesty and integrity seem to be homely anachronisms in a day when financial experts warn the public not to sign proxies in the form of punched cards! With the erosion of accepted conceptions of virtue and ethics, both the moral fiber and the mental health of the society may be seriously affected. Emile Durkheim, the eminent French sociologist, found that the breakdown of precepts without the substitution of meaningful guidelines leads to a state of <u>anomie</u>, sometimes translated as "normlessness," which can perhaps be described as a kind of psychological limbo. A manifestation of alienation and inability to relate to the larger society, anomie in its more extreme forms was regarded by Durkheim as a major cause of suicide.[9]

Durkheim observed the anomic phenomena of social isolation and loss of sense of community primarily in connection with the division of labor and the greater specialization which accompanied industrialization.[10] His hypotheses have been substantiated by research on the effects of automation on workers. Psychiatrists at the Renault factory in France, for example, discovered a high incidence of mental breakdown among persons whose tasks consisted of monitoring machines and dials and who had little opportunity for interaction with others. My own studies of the impacts of automation on the clerical labor force indicate that anomie is a prime, but rarely acknowledged, occupational hazard.[11] As more categories of jobs become integrated into computerized systems, not only routine clerical tasks but also many formerly the province of middle management are undergoing change. Even top decision-makers complain of the encroachment on their executive prerogatives; in multi-access, shared-time systems, they must queue up no matter how urgent they may regard their particular request of the computer. It will reply in its own, sweet, programmed time!

Technology in the home has not been without its anomic consequences: While pushbutton housekeeping devices may have freed the homemaker from

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[9] Emile Durkheim, Le Suicide, Paris, 1897.

[10] Emile Durkheim, De la Division du Travail Social (Paris: Ancienne Librairie Germer Bailliere et Cie), 1893.

[11] Ida R. Hoos, Automation in the Office (Washington, D. C. Public Affairs Press), 1961, pp. 13-15, 68, 69, 75, 109, 126.

some heavy work, they have also deprived her of a rationalization for hiring outside help. She now can do everything herself, and is left with only small children as companions. Dr. Roger Revelle, Director of the Center for Population Studies at Harvard, told a Senate subcommittee that he considered the modern American woman "one of the lost souls of our technological society," lonelier and harder working than her mother and grandmother ever were. If the lady of the house feels isolated now, what are her prospects when she will not need to move from her television set to get her shopping done? Electronics experts predict that by means of visual displays and telecommunication, she will not only be able to signify her choice of fruit and vegetables to her grocer but she will also be able to select gowns and furs from Paris salon displays and items for household decor from the exotic bazaars of the Orient.

But before we progress too far down the road toward making shut-ins of American mothers, we might do well to examine the psychological benefits to be derived by her and others from the social experience of shopping, to say nothing of the excitement and fun of foreign travel and discovery. One might even do a longitudinal study, looking back through the pages of history for insights. I suspect that the functionality of meeting at the trading-post or around the pot-bellied stove would far outweigh the dys-functionality of having to spend the time to get there. In fact, I see evidence for assuming that shopping remains a generally popular activity from the day when one first achieves the grown-up responsibility of going to the store on an errand for Mother. According to a survey by Dr. Alice S. Rossi of the National Opinion Research Center at the University of Chicago, 82 percent of the 9,980 young, college-educated wives questioned put shopping high on the list of chores they enjoyed, while cleaning and washing rated very low.[12] Retired couples seem to make quite an outing of the trip to market; they linger over the cases, ponder each item, and chat at length with clerks and acquaintances. All this apparently provides a welcome respite from the monotony and isolation of which they are wont to complain. The neighborhood shopping center probably offers as much diversion as most programs of artificial sociality for senior citizens.

The pressures and frustrations of modern life are seen by Dr. Erich Fromm[13] as contributing to a major change in the nature of psychiatric problems and calling for a new kind of treatment. The Freudian conception of the subconscious mind was one of repressed sexual desires and fantasies derived from a Victorian era. Such a view is no longer relevant. The past half century has witnessed an upheaval in mores, and, in our consumer culture, sex is a merchandising device and item. Fromm maintains that we are now prone to suffer from a "social unconscious," made up of repression of anxiety, depression, loneliness, boredom, and pain about the meaninglessness of life. His diagnosis: "Theologians and philosophers have been saying for a century that God is dead, but what we confront now is the possibility that man is dead, transformed into a thing, a producer, a consumer, an idolater of other things." His remedy: "(1) Remove the fear to feel, think, and express what is real in oneself and society; (2) Increase the capacity to think critically, to question, and to be skeptical; (3) Promote a renaissance of humanistic thought in which the highest value is the spiritual development of each man."

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[12]"Consumer Communications--A Symposium," Management Review, April, 1967, p. 11.

[13]Dr. Erich Fromm, Address at American Orthopsychiatric Association Meetings, San Francisco, California, April 14, 1966.

Technological Civilization and Privacy of the Individual

It is the supreme paradox of our age that man runs the danger of becoming psychologically more unrelated to his society and at the same time more engulfed by it, all thanks to advancing technology. Although he may "go down to the vile dust from whence he sprung,/ Unwept, unhonored, and unsung,"[14] he will have generated lots of data, in the form of cradle-to-grave records, and Big Brother will be interested in all of them. Even if there were not the distressingly real possibility of spying, eavesdropping and control of thought by electronics, there would still be the serious problem of invasion of the rights to privacy in a society where data-gathering, storage, and retrieval have become a compulsion. From county to Congress, government bodies which used to have to juggle their accounts to squeeze out an extra typewriter ribbon can now command hundreds of thousands of dollars in the name of "systematic planning" or "scientific operation." The importance and efficiency of a department can be judged by the size and power of the electronic data processing equipment it has or can get approved. And with the acquisition of costly hardware and software, there has developed a new cadre of specialists inhouse and outside--the information technologists.

Statistical technology, it must be noted, is not new to the government. Some 21 federal agencies maintain programs for the collection, processing, and dissemination of data, and techniques for acquiring, analyzing, and collating information and using it for economic, social, and political studies have been developing for years. The advent of the computer simply represented the next step in a natural, historical

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[14] Sir Walter Scott, "Patriotism."

progression. In the view of some professional statisticians,[15] "The very general logical powers, the great storage capacity, the high speed of manipulation, and the low unit cost of modern ADP (automatic data-processing) systems combine to promise great potential in information resources and problem-solving capabilities." Such "improvement" implies less duplication and more efficiency, the very factors underscored by Dr. Carl Kaysen in his arguments in favor of a Federal Statistical Data Center.[16] Dr. Kaysen, who is Director of Princeton's Institute for Advanced Study and who headed the government committee which recommended creation of such a center, apparently intended to reassure those who regard such a data-bank as a peril to privacy and a threat to a democratic society. He only succeeded, in the sections called "Anxieties" and "Temptations," in calling attention to more areas for concern than outsiders might otherwise have identified. His credo that "the present balance of forces in our political machinery tends to the side of healthy restraint in such matters as these,"[17] is not universally shared.

The national information system, which appears to be the most recent development in the historical progression, will provide an instant check on any American, with complete details on his birth, color, religious and political affiliation, school grades, employment, criminal or military record, travels, credit rating and medical history. It may be noted that the argument for greater government efficiency has moved us from acceptance

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[15] E. Glaser, D. Rosenblatt, and M. K. Wood, "The Design of a Federal Statistical Data Center," The American Statistician, Vol. 21, No. 1, February, 1967, p. 14.

[16] Carl Kaysen, "Data Banks and Dossiers," The Public Interest, Spring, 1967, pp. 52-61.

[17] Ibid., p. 60.

of improved statistical systems to engulfment by an intelligence system.[18] The former, which deal with characteristics of aggregates or populations, give averages and percentages which relate to no one person; the latter, by contrast, generate data about individuals *qua* individuals. Even if a man's past contained nothing like a mental illness or a conviction to render his present and future a Sisyphean struggle, he could be tabbed by some agency's search into the giant memory of the computer as a potential member of some "risk" population, e.g. criminal or welfare, and subjected to embarrassment or harassment. At the American Orthopsychiatric Association meetings last year, Dr. Orville G. Brim, Jr., president of the Russell Sage Foundation, deplored the ugly alliance developing between legal-electronic surveillance, scientific research, and government dossiers, all wearing a benevolent, scientific disguise.

Under the chairmanship of Congressman Cornelius Gallagher (D., 13th District, N. J.), a special Subcommittee on Invasion of Privacy held hearings in mid-1966 on the proposed data center. Witnesses expressed opposition on various grounds: (1) the generally recognized dangers of a dossier bank; (2) the computer's refutation of the Christian hope of redemption,--with no forgiveness for youthful pecadilloes or extenuating circumstances; (3) petrifaction of unreliable and inaccurate data. The sociologist's point of view was later reflected in a statement by Professor H. Taylor Buckner:[19]

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[18] Edgar S. Dunn, Jr., "The Idea of a National Data Center and the Issue of Personal Privacy," The American Statistician, Vol. 21, No. 1, February, 1967, p. 23.

[19] H. Taylor Buckner, Letter to the Editor, The American Sociologist, Vol. 2, No. 1, February, 1967, p. 25.

> To argue in favor of a National Identity and Data File requires the assumption that all future governments of this country in all political situations (including war hysteria and witch hunts), all federal agencies both public and secret, and all individuals who could gain access under the cloak of authority or by ruse, will be benevolently motivated. I do not think that this assumption can be made by a reasonable man. The potential for evil, for official and unofficial blackmail, for the harassment of political minorities is virtually unlimited. One must realize that whatever safeguards may be proposed in the initial justification could later be removed by a powerful president or a stampeded congress. Also the safeguards probably would be circumvented on or off the record by our undercover agencies.

The computer's capacity for information digestion has contributed to reification and deification of data to such a point that the observed tendency is to program first and select later. Everything is "tossed into the hopper," with the idea that something worthwile might be "teased out" of the computations, compilations, or manipulations. Early IBM users used to display on their walls a framed message, "Think." Later, this was informally amended by ambitious executives to "Think Smarter." It could now be changed to "Think Later"! In criticizing the notion that data are *ipso facto* good, Professor Thomas A. Cowan[20] made the cogent observation that it has become a matter of prime policy to determine what data shall be preserved and which it is politic in any instance to be allowed to be recalled. His recommendation for "creative unlearning" or purposeful forgetting comes from his experience in the practice and philosophy of law and is extremely apropos in view of the threat to privacy inherent in the capability for the electronic matching, coordination, and instant recall of large masses of information about individuals.

All for the sake of improved efficiency in systems purportedly designed for his betterment, man was first assigned a number. Next, the number became synonymous with the man and was accepted by the system for

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[20]Thomas A. Cowan, "Decision Theory in Law, Science, and Technology," *Science*, Vol. 140, June 7, 1963, p. 1070.

processing. Then, the system began to treat man like his alter ego, the number. Further depersonalization is in view as the devising and handling of systems becomes an occupational specialty, the bailiwick of a newly emerging cadre of information technologists, who approach social problems from the quantitative, machine-soluble point of view. Moreover, unlike molecular biologists or nuclear physicists who have the excuse of extremely theoretical and abstract matters to justify their lack of communicativeness with the general public, this group deals with subjects vital to the life, liberty, and pursuits of every living being. But, because of the increasing complexity of their metier, they operate in a world apart. They construct what they conceive to be appropriate models of the systems all about us on the assumption that social systems are subject to the same rules and manipulations as missile systems. Because of a widespread tendency towards an "Emperor's New Clothes" with respect to the computer and all those who bask in its charismatic glow, decision-makers have been reluctant to question the recommendations of the systems engineers and, even more important, to challenge the appropriateness of their models. Because "scientific" models mechanize the concept of man, there is a kind of self-fulfilling prophesy here: A technical society will engender technical minds unable or unwilling to grapple with such immeasurables as social costs and human values.

Conclusion

A popular and somewhat irreverent ditty from times past sang of King Solomon and King David who, when they were young, "led merry, merry lives,/ With many, many lady friends/ And many, many wives./ But when old age came to them,/ With many, many qualms,/ King Solomon wrote the Proverbs,/ And King David wrote the Psalms." So likewise goes the life pattern of the scientist. In the early days of his career, he labors under the conviction that science is outside the moral sphere. Secure that his quest for knowledge is purely theoretical, he remains aloof from the possible applications and consequences of his work. But the illusion of pristine purity can no longer be preserved even in the super clean laboratory. When the scientist reaches maturity, he recognizes that theoretical research has deep significance for all mankind. High energy physics and its relation to weapons development, bacteriology and its potential in warfare, molecular biology and its implications for selective genetics are but a few examples.

Dr. I. I. Rabi,[20] in his valedictory speech ending a 40-year career at Columbia University, deplored the isolation of science from ethical considerations. "The fact that a system of ideas works," he stated, "is no guarantee of truth." Glenn T. Seaborg, Chairman of the U. S. Atomic Energy Commission, pursues a swords-into-plowshares course and takes comfort in the notion that the future is far off![21] His statements indicate that he is not too convinced that we thoroughly understand all the ramifications and implications of what we are doing, for he welcomes at least some of the criticisms of technological advance. "They remind us that we are part of ecological and social systems involving many delicate balances. They make us move cautiously, broaden our thinking, and temper the tendency we may have to seek quick technological answers to many natural and human problems which are not so quickly or simply solved."

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[20]John Leo, "Columbia's Highest Professor, I. I. Rabi, Ends 40-Year Career," New York Times, May 18, 1967.

[21]Glenn T. Seaborg, "Man Must First Choose Goals," Technology Week, January 23, 1967, pp. 32-35.

Dr. Rabi, once a consultant to the atomic bomb project and more recently dedicated leader among scientists seeking disarmament, recommends an interpenetration between science and the humanities. Dr. Seaborg urges that mankind identify its goals; he sees as responsible in the process not only scientists and engineers but educators, social scientists, and statesmen as well. But if human values are really to prevail, if the ultimate social good is ever to receive sincere regard, then we must first recognize the fallacy of assuming that the opposite of logical is illogical, that the opposite of rational is irrational. It is on these grounds that an accusative case has been made against man and society. This specious dichotomy has provided justification for ruling out the human element and for constructing purely "technical" models of society. For us pre-1984 dwellers, "Mene, mene, tekel, upharsin" has special meaning: It is that science and technology must be a part of instead of apart from man's moral commitment to the past, present, and future of all mankind.

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ETHICS OF LARGE SYSTEMS

C. West Churchman

I am going to start by telling you about some recent developments called operations research and management science and then draw some implications of these recent attempts that I think will be of interest to this audience. I will be talking about long-range planning of our society, something that's concerning many of us these days. In some sense the previous two speakers gave us an answer to long-range planning. If we wait a few billion years for the next bang, then all of our planning function is taken care of. Perhaps the design of DNA systems will also take care of it for us, but meanwhile in the shorter range of the next few decades or centuries, human society has to understand why serious social troubles have occurred and whether there is anything that we can do about it, using our intellectual abilities as well as all the other resources available to us.

So I am really turning now from the picture of the universe as a living thing or as a physical thing to the internal picture of the human soul, with somewhat the spirit of Immanuel Kant's remark at the end of his Principles of Morals, where he says that two things fill his heart with never-ending awe, "the starry heavens above and the moral law within." Kant was concerned about the ways in which man's intellect can understand the ethics of man's conduct, in particular the ways in which we can distinguish between improvement and detriment in human societies.

The story I am going to tell you is concerned with an effort that started in World War II to use teams of scientists trained in all kinds of disciplines--mathematics, astronomy, biology, social science, whatever--to assist managers in understanding the basic properties of their systems and determining ways in which, via science, these understandings could result in improvements. The phrase we have come to use for this activity is "operations research," because the initial work was done for military installations, and specifically for that section of the military called operations. The movement has gone far beyond its military applications but we still have the label. Some have felt that perhaps it is more desirable to use a more descriptive label like "management science" or "systems science" for this effort. But whatever label is used, it means bringing into the managerial setting people with training in various disciplines of science with the expectation that their way of looking at nature in a fairly precise and rational fashion will be of assistance to the manager in unearthing the really basic causes of systems troubles. These troubles may occur in the military, or in industry, most especially nowadays in our urban society, in racial disturbances, in transportation, in education and in health. In all these problems scientists are trying to assist the managers in understanding how to design in more rational fashion the kinds of systems that are very important to us. For example, the Department of Health, Education and Welfare now conducts a number of studies which fall under the general head of systems science.

One label that is used in government circles these days for system science studies is "cost benefit analysis," which reflects the idea that the systems we design must develop certain benefits to the human being. But evidently whatever the system is it also exacts certain costs, and by properly looking at the system one may be able to discern the true benefits and costs, and begin to evaluate which particular education system, or health system, or transportation system, is most appropriate.

I am going to describe for you some of the method of the systems approach that has been evolved in the last two decades, then say some things about how it has been applied, and then go on to some of the basic philosophical problems that I think arise from it. Essentially the method is the method of science and hence creates a model of the system. What we try to do is capture either by mathematical methods or by computers a description of the system that we are considering. If it's an educational system, we try to get the computer to simulate the activities that go on in school--the students coming in, the typical needs that they have, the kinds of courses they get, the probable level of attainment they will reach at each stage, and so on. Once we have simulated the school, we can experiment with certain changes in the system and determine which of these changes appear to be desirable. We can do so without changing the real system. Thus we can use our mathematics or computer technology to assist us in understanding the system and experimenting with it, and try then to judge which change will be best.

The models by themselves, however, will mean very little unless we collect the data that must go into them; our data must tell us how well a system satisfies human wants and needs and what costs are entailed in providing the desired kind of service. For example, if we look at a transportation system like the freeways of San Francisco, we try to determine what needs there are to get people from one place to another within the city. Then we try to get data that tell us the extent to which freeways are a good method of solving some of the basic transportation needs. Finally we try to determine what the costs are of each possible transportation system, and see whether the difference between benefit and cost from an economic point of view, warrants the construction of additional freeways.

The same methodology can be applied to a health system, or to education or recreation; in all these instances we are trying to examine the total system, to understand how it works and then by our models to make predictions, fill in the costs and benefits, and make a judgment about them.

The method of operations research and system science relies more heavily on mathematics than do most of the social sciences, but it nevertheless fits into the pattern of the social sciences as well as the physical sciences in its approach.

Operations research, as I said, had its beginning in World War II. That doesn't mean, incidentally, that it hadn't gone on before. In fact, in Plato's time many scientists and thinkers of Athens were convinced that there was a way to understand the city-state "system" that would enable them to develop optimal designs for serving the needs of all the citizens. Plato's Republic is one extant document which by anybody's standard could be regarded as a systems science textbook of the fifth century B.C. Naturally, we can criticize his work, just as everybody has some criticism of current systems science, but the Republic is Plato's estimate of how one particular system ought to be run. And from Plato's point of view, he was using the best "scientific method" of his time.

Nevertheless, the work of the last two decades has been quite fantastic in the amount of growth of interest there has been in using scientists in the study of human systems. I estimate that in the United States there are about 6,000 people who have been trained as engineers and scientists in many different disciplines and who are actively engaged in systems science; there are an additional 5,000 who are engaged in something close enough to it, so that the total amount of effort being poured into this particular area, compared to what was done twenty years ago, is fantastic. The students we educate here at Berkeley and other schools usually have an enormous number of job opportunities; the need is far beyond the supply of scientifically trained personnel--to study management problems.

I think the change of philosophical attitude that has occurred is that (1) managers in the twenties and thirties never even thought of trying to use people outside of business schools and economics to assist in the solution of their problems, and (2) scientists themselves in those two decades never thought that their particular training could be of very much use to managers. But the experience of World War II and afterwards has shown that scientists do appear to be useful, that apparently great gains can accrue if one tries to look at social systems by the use of the scientific method.

So far my remarks have been on the positive side. If I were here as an operations researcher wanting to get a contract with one of your many churches, I would then stop my talk at that point and say that there is absolutely no reason why operations research cannot be applied to the management of the diocese or church. You have many administrative problems where it is amenable and I would have slides to show what gains might accrue. In fact, some of it is already occurring, I gather, in some churches.

But my purpose here is not to talk on that level but rather to address myself to what I consider the very basic serious and deep philosophic problem that we face, all of us, whether scientist or not, in our attempts to improve social conditions. I'll take off from a technical idea and elaborate therefrom. The technical idea is something in our work that we call the "opportunity cost." It would be very nice in our analysis if we could just go out, and look and see how much a given plan will cost, e.g., how much a freeway costs to build, how much a given plant costs, how much it costs to build a grammar school, and so on. It would be nice if we could express all costs in terms of dollars, the dollars the manager has to spend to implement a change. But the trouble is that every time a resource is used up in creating a new educational system, there is a sacrifice incurred throughout the system. People have to give up something in order that this particular kind of system may be created.

In recent months we have seen a very fierce debate going on because of Governor Reagan's policy with respect to mental health. Behind all that debate is a philosophy of opportunity costs. Reagan apparently believes that we are sacrificing too much in the care of mental health beyond what is really required, and that the savings that would accrue by cutting back on those expenditures would be on the whole beneficial to society. His opponents do not agree. In any event they are both talking about the same concept--namely, how a particular part of our social system either uses up resources or does not, and how that affects the other parts of the system.

We quickly find then that in a human society such as we live in today the sectors, these so-called "systems," are all interrelated. That's nothing new to any of you that have been involved in social work. But the sectors of society are interrelated in very strong terms. You can't simply talk about using some money to build a new school building without worrying about sacrificing some other program which is of even greater importance. Not only that, but when we talk in these terms we have to worry about whether if the resource were available it would be used correctly. So whenever we look at a small part of a system, like the transportation system, we have to be asking ourselves whether if we didn't build these freeways and used the funds in other ways, we would really know how to take the opportunity correctly. Hence "facts" that we are trying to collect become a kind of universal judgment. If I say it's a "fact" that it costs this much to build a school building, then that fact reflects some judgment about the total system.

Hence those of us that have been engaged in system science begin to understand that in order to improve social systems, wherever we do it, we are making judgments about the nature of the whole system. The facts that we wish to put into the picture are facts that relate to the characteristics of the whole social system.

There is nothing particularly new philosophically about this way of understanding things. Philosophers throughout the ages have seen that the need to understand the whole system was an essential need if you were going to try to approach social improvement by rational method. And so they tried to write down the story of what the whole system looks like: Plato, Aristotle, St. Thomas, Hobbes, and in the nineteenth century economists and historians like Marx and Spengler, were all trying to depict the nature of the whole system as a basis then on which they could understand social improvement.

The trouble as I see it today is that none of these classical, historical pictures gives us enough detail and confidence so that we can use them in understanding how we should approach systems design. In fact, I conclude that there is really no known method available at the present time of understanding enough about the properties of the whole social system to be able to enable us to estimate firmly the true costs and benefits of social change. And this moral applies to technological innovations of the type Ida Hoos talked about as well as to the design of educational systems, transportation systems, and the like. We simply lack the basis for understanding enough about this whole social system.

The problem becomes even more critical if we look ahead into the future. The future is what interests western culture; we are much more concerned about the future than we are about the past, as you can tell from all of the talks we have heard. In fact, we keep emphasizing that the future is the important thing. Now from the system's point of view, the question is: how much do we understand about what we are doing today that will affect the lives of the people in the next generation and beyond? In the 1960's there has been an increasing interest in the future. For example, a commission was recently appointed to say some things about the year 2000, to predict the events that may be beneficial or may be detrimental. Do we know enough as we change our society to be able to predict the consequences, not just for the next generation but for a century or five centuries hence? Of course, the answer is no, not only because we can't forecast what's going to happen, but also because we don't really know how to put these pieces together. We don't know how to put the next generation into a relationship with this generation.

What's to be done about it? There are several reflections that one can have in the face of ignorance. One is give up. That's the sceptic's answer. Every freshman who takes the course in philosophy "suddenly" discovers this answer. It's a marvelous discovery. It's obviously valid. We don't know what we are talking about. The professors don't certainly, and even the students don't at times. And so the answer is we human beings live in an environment which we don't have the intellectual capability of understanding. So do anything that you can but don't really believe it matters.

Closely allied to the sceptic is the sophomoric determinist who suddenly discovers everything in reality is completely determined regardless of what we do. Therefore it really doesn't matter what we do because it's all been predetermined before. This fellow is especially delighted when he reads Spinoza's Ethics to find there even was some other chap back there in history who had the same idea; that essentially all we have to do is understand that the world is determined and that's it.

But determinism doesn't do for energetic, red-blooded American men. They don't like to look at the world either sceptically or deterministically. Determinism and scepticism don't do for the deeper, philosophical reasoning either. Scepticism I regard simply as a vacation we are all entitled to take from time to time. Beyond that, when you get back to being serious and an adult again, you have to give it up. Determinism is also a kind of vacation. There has never been convincing philosophical evidence for it. It's a way of looking at the world, and there is no question you can look at it that way, but having said this much, that's all you can say. And there is a richer way of looking at the world, and that, as Aristotle said, is in terms of the purpose. We are purposive human beings, we do have choices, and that's a reasonable way to look at ourselves. But will our choices lead us to eventual disaster?

Now there is an answer to this question that's to be found in the history of science. As you listened to Professors Weaver and Jukes this morning, you must have been impressed by their modesty as well as their conceit. They both claimed that there were large areas that they did not know about; in a way they became more excited when they began to speculate about the immensity of the mystery as compared to the immensity of knowledge, because mystery is what excites the scientist. He has always lived in the atmosphere of the unknown. The point is that the method of science consists of a gradual approximation. Each time we learn something that adds to our sum of knowledge, we have to admit that at the same time beyond those domains of knowledge lies the great Unknown. But we will gradually go from decimal place to decimal place in pushing on the frontiers of knowledge. Consider, for example, the measurement of length. Bishop Berkeley said in one of his books that a length smaller than one-thousandth of an inch is ridiculous because nobody can possibly perceive something less than one-thousandth of an inch. One-thousandth of an inch was the limit of meaningful accuracy in Berkeley's time. Today it's at least a ten-millionth of an inch.

Here then is an answer. We can say to the managers and politicians that as scientists we can't solve their big systems problems. Let us first work on smaller aspects, and then we'll begin to understand some things and make some changes, being careful not to make irreversible changes that may ruin everything. After we've made some small changes, we'll be learning a little more about a larger system, and then a larger one, and then a still larger one. The story of the Department of Defense is a good example. Here the operations researchers started out very modestly working on small problems in the field. Then they got promoted to working for departments of the Air Force and the Army. Then they got working for the whole Air Force and the whole Army. Then along came McNamara, who put some of them together on a team that's studying the whole Department of Defense planning and budgeting. But that's not the end, because now the major problems of the defense of this country don't lie in the Department of Defense. They lie in the Department of State. So what is now needed is a more integrated Defense-State Department system. But that's not the end either, because evidently Health, Education and Welfare, Commerce and so on represent part of a still larger system. And after a while we'll march on and begin knocking on the door of the UN. So a world system will begin to evolve.

All this has been an optimist talking. He says that by taking gradual steps and making changes we'll be able to increase our understanding of human systems; we can look ahead to a time of gradually accumulated knowledge, always admitting that there will be great unknowns and great mysteries, as there are in all of the sciences. This philosophical answer called "progress" was extremely attractive in the nineteenth century. It formed the basis of a great many philosophical writings of that period both in this country and in England.

But the philosophy presupposes a basic rationality of the universe, and particularly of the rationality of social systems. It says in effect that there is such a thing as a rational approach to social systems, and furthermore it says that the human social system is embedded in an environment which will continuously provide us with the opportunity for intellectual understanding. It says that the conditions under which we live provide at least the opportunity for the human being more and more clearly to understand the social system and to improve his measurements of it in terms of costs and benefits, and gradually to begin to solve some of the basic problems so that he can move on to the richer problems of human living.

Meanwhile we must admit that we are still ignorant about the nature of the social system, even though the system does exist. We know that it is far from optimal and we don't know how to improve it. The whole social system develops its own kind of morality, its own kind of ethics; it looks almost as though the individual managers and scientists who live within the social system are at best creating perturbations that may be good, may be bad, may be nothing. It's easy for us to pick out some manager, or politician, and simply identify him as the evil force when trouble occurs. Whereas I think the more honest thing to say is that in all of these situations we are involved in problems of the whole system, and since we don't really understand them, the systems themselves carry on their own kind of morality, often to the detriment of their inhabitants.

Nevertheless, the optimist is going to argue that we will gradually begin to understand the basis of war, or of starvation, and gradually move ahead to social improvement.

But as scientists we have to do more than state our optimism; it's up to us to explain why our optimism is valid, to provide the evidence for progress. Because there does seem to be some good evidence against optimism.

Hence the major question that I think all system science faces today is the question of whether there is something about man and his resource environment that does guarantee a gradual improvement, or at least the opportunity for gradual improvement. Is there something about the nature of reality that tells us that the opportunity is there? Or is there something about the nature of reality that tells us it isn't there? Either side has to make its defense. This of course is not a problem peculiar to the scientist. It's a problem that's central for all managers as well. They must ask themselves as they go about changing things, whether in the changes they produce they believe they are making improvement or not. The industrial manager is fortunate because he has a balance sheet and can say "we made so many more dollars this last year." He doesn't however ask the real systems problem. He doesn't ask whether those dollar benefits are <u>real</u> benefits from the point of view of either his own system or the whole system.

Now this question I've raised--whether there is something about reality that guarantees the opportunity for gradual improvement of the social system--is an old question. It was, I would say, the central question of science of continental Europe of the seventeenth century. The great scientists of that time, Descartes and Leibnitz, took the problem to be fundamental for all science. The foundations of science, they said, could only be constructed by first proving that total deception is not possible, and that scientific approximation to approximation is in some sense guaranteed. In the language of system science, we need a component of the system which is a guarantor of the design. In these days of alphabet soup, we can best represent that component as a Guarantor of Design, and say that basic to all system science is a GOD.

Now take the problem of the guarantor to be a theological problem as did both Leibnitz and Descartes. It's a theological question that science largely ignored for various historical reasons. But if we are going to take systems science seriously and if we are going to say that the systems scientist and the applied scientist can help the managers to improve the world, then it seems to me that systems science desperately needs a theological foundation. When I say this to my graduate students in Business Administration they look very skeptical. When I suggest that what we really need is a basic course in theology in the business school in order to study the problem of the guarantor of system improvement, they think I am perpetuating a philosophical joke. But I'm not; I'm quite serious.

There is a commonly shared question among managers and theologians and scientists, the question of the guarantor of man's opportunity to improve his social system. Now, admittedly in the sharing of that common problem, there is an enormous problem of communication, because theologians don't talk in terms of system science language. But common issue is there nonetheless.

I'm not sure that the answers that the theologician might give would be the answers that the system scientists would want to accept. But that doesn't preclude the alternative answers being discussed in as open a way as possible. I have used the term theology rather than religion. I meant theology as a science, in the sense that theology ties into the scientific enterprise, and hence provides us with some sound basis of understanding of whether or not reality has the characteristics that guarantee the approximation-to-approximation philosophy. I must admit that it disturbs me that we hand over so cheerfully the direction of the planning of large human systems to people who must be intellectually blind, however brilliant their minds may shine. Perhaps the intellectual shyness that seems to occur in creating conversations between scientists and theologians may diminish in time so that applied theology takes its place among the other applied sciences, engineering and applied social sciences. Perhaps, if we work hard on it, the applied theology will help to build a saner social system.

THE PRESENT DAY VIEW OF THE PHYSICAL UNIVERSE

Harold F. Weaver

The goal of the astronomer is to understand the universe in its largest sense; to understand the position of the earth and the planets in the scheme of astronomical birth and evolution; to understand the properties, motions, and characteristics of the stars, and the galaxies they form. He tries to understand how the stars are formed and how they evolve and what the processes of change imply about the future of the physical universe.

The only contact that the astronomer has with the universe in the large is through radiation. On the earth the physicist can experiment, can try things, but in the case of the larger universe we can only see what is there. We cannot experiment directly; we cannot perform any modifications on the system. We can only look. We can only observe and attempt to interpret what we see on the basis of the physical laws that are derived in the laboratories on earth.

In the process of observing and interpreting, we should make an effort to sample radiation of all types. The fact that we are now viewing the universe by means of radiations different from those that have been utilized by the astronomers in the past marks one of the great advances in this field of science. In the past, astronomers have normally used the optical range of the spectrum (to which the eye is sensitive) to view the universe. But there is a great deal of spectrum--a great range of radiation--that lies outside of the visible range. The full electromagnetic spectrum encompasses radiowaves, infrared waves, visible light, ultraviolet, X-rays, gamma rays, and so on. I have here named portions of the electromagnetic spectrum starting with the longest waves and proceeding to progressively shorter waves.

Only recently have we begun to use the full range of the electromagnetic spectrum in the exploration of the universe.

The physical processes that go on in stars and in other components of the universe produce radiation of different characteristic wavelengths. If we examine the universe in a certain wavelength range, we are viewing the universe as it is characterized by a certain physical process. Thermal processes produce most of the visible light. The hot filament in a light bulb, for example, produces radiation; it radiates radio waves, infrared, normal visible light, X-rays, gamma rays. But in most of these wavelengths, the light filament radiates in such small quantities of energy that for practical purposes we can neglect these ranges. By and large, the temperatures of the stars are such that they generate only a small fraction of their radiation in the radio and X-ray ranges. The stars (by thermal processes) produce the largest fraction of their radiation in the spectral range to which our eyes respond. Since most of our contact with the universe has been through radiation in the wavelength range to which our eyes are sensitive, we know the universe primarily as it is represented by objects which are quite hot and produce most of their radiation in the optical or visible range of the spectrum.

We should keep in mind, however, the important fact that different physical processes (all of which we must try to understand if we want a complete picture of the universe) produce radiations of different characteristic wavelengths. To see the whole universe in all its complexity, we must use a large portion of the electromagnetic spectrum extending from the radio range to the X-ray and gamma ray range. We have, up to the present, been using primarily the optical portion of the spectrum, so our view of the physical processes in the universe,and therefore the universe, has been very limited indeed. We are now starting to gain new insights by using other ranges of the spectrum, and I will have more to say about that in a moment.

But, now that the slide projector is finally working, I can show you some pictures. I thought I might start by trying to establish the scale of the universe. When you see the pictures I want to use for this, you must realize that we are viewing the universe in a narrow spectral range. Unfortunately, there is no radio camera that will take pictures in radio radiation and there is no equivalent x-ray camera though there are detectors that will permit us to view the universe in these different ranges. Generally, we will have to use drawings, charts, and other representations to picture what we "see" in these other ranges. To make a rapid tour through the universe and to describe the scale of distances, I need some sort of a measuring stick. I will use the familiar one involving the velocity of light--that is, I will talk about a light second, a light day, a light week, a light month, a light year, and so on. Light travels 186, 000 miles per second; a light second is a distance of 186,000 miles. A light year, quoted in miles, is simply 186,000 multiplied by the number of seconds in a year--approximately 6 followed by 12 zeros. It is simply an enormous number. It's easier to say "a light year" rather than such a number, and I hope the term light year will convey some idea of great distance.

The first slide shows a picture of the moon. I feel amost apologetic to say this a picture of our natural satellite--we have so many artificial ones at the present time--and it represents the nearest of the objects normally studied by the astronomers. It is very close indeed by all of our contemporary standards. It's about 1-1/3 light seconds away, so we reach it very quickly indeed if we travel with the speed of light.

Next slide, please. In these first pictures we are quickly moving through the solar system, traveling on a beam of light. In about half an hour, having traveled a distance of about 30 light minutes, we would reach the planet Jupiter, one of the largest of the planets of the solar system, one that lies substantially outside of the earth's orbit. Remember the sequence, Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, Pluto, and beyond--we'll soon be beyond. We speed by Jupiter and move on to the next planet Saturn, which I show here primarily because it has a beautiful ring. It is a unique object in the solar system. We move on by Saturn and, after about five and a half hours of travel at the speed of light, we reach the extent of the system of planets and move out into the realm of the comets. The comets form a kind of halo around the planetary system. To go beyond out into interstellar space, we pass through the realm of the comets which would require about half a year to traverse. The comets occasionally come in close enough to be seen, to be visible, as this one was in 1957. The comets we see generally come into the region of the sun on very elongated orbits moving sunward from among the great swarm of comets that extends out to distances of something like half a light year. When we pass the limit of the halo of comets, we move outside of what we think of as the solar system. Starting from the Earth, we would move out for half a light year or so in distance and we would then be out in interstellar space.

The next picture is a drawing of the Milky Way and shows the system of the stars to which the sun belongs, the system we speak of as the Milky Way or galaxy. We see here some of the objects we are going to examine. In the process of moving out among the stars on our light beam, we would find that we have to travel for more than 4 years (always at the speed of 186,000 miles a second) to reach the nearest of them. To move from one star to another, we would have to travel roughly for this same period of time--some 4 years or so. I can illustrate the situation with a model. (Astronomers and physicists are always building models to help them in their thinking, and perhaps one will help you.) If we build a model of the stellar system, we could represent the stars by pinheads--which are easy-to-come-by objects--and we have to locate these pinheads essentially randomly around in space to represent the stellar distribution. We would place the pinheads 10-15 miles apart on the average. Although they seem numerous beyond counting, the stars in their courses are lonely indeed.

The next slide will show an actual photograph of the Milky Way. You remember on the last slide how the Milky Way was concentrated towards a certain plane in the sky. There was a greater density of stars in one region of the sky than in another. This is because the galaxy is a flattened system and the sun is located roughly in the plane of that system. When we look in this plane of stars, we see a greater number of them than when we look perpendicular to it--our view goes quickly through the plane of stars and we see fewer of them. When you examine a photograph of the Milky Way you notice at once that the stars are not uniformly distributed; there are many dark areas. This is caused by the fact that the space between the stars is not devoid of material. There is a great deal of gas and dust-like material between the stars. Where there are great accumulations of this nonstellar material, dark clouds are seen. These obscure the stars that lie behind them as you see in this picture. The next picture of the Milky Way will show much dark nonstellar material that obscures the stars which lie behind them. There are also here, as you can see, little wisps of material, gas that is illuminated by imbedded stars and which shines as luminous clouds.

A moment ago I tried to give you some idea of the scale of stellar distances by proposing a model made with pinheads. I will try to give you an idea from time to time about the scale of distances involved in the photographs. In looking at these stars which are sort of randomly spread on this photograph, we are looking at a wide variety of distances. Some of these stars are quite nearby, as stellar things go, perhaps only 10 light years, a hundred light years, a thousand light years, and a few of them are many thousands of light years distant. So, we are here looking at a great variety of distances. This is generally true of the pictures we shall be seeing.

The next slide is of an area of the sky that I think many of you will recognize. It's a portion of the constellation of Orion and you will readily note the belt and the sword handle. I show this for two purposes: first, to call attention to the fact that stars have quite different characteristics even to the naked eye. Their different characteristics become even more apparent when they are investigated by the telescope and by various physical instruments. You may recall the bright star, Rigel, which is so blue, in the constellation of Orion. All the stars in the belt are quite blue; in fact, one of the bluest stars ever measured is in the belt. There are also red stars, Betelgeuse, for example, in the constellation of Orion, or, if you remember the summer sky, Antares, the red star in Scorpius. Stars are quite different in their characteristics. They go through the whole sequence of colors because they have different surface temperatures--the hottest ones are blue, the coolest ones are very deep red; there is a wide range of stellar colors and temperatures. There are different sizes; the star Betelgeuse, for example, is a very large one. A large portion of the solar system would fit within its surface. The blue stars are very hot; they are expending their energy at very great rates. That energy comes from thermonuclear processes that go on in the centers of the stars at very high temperatures, 10-20 million degrees. These blue stars are interesting in that they provide an example of a rapidly evolving object. One can readily compute that they are putting forth energy at such a high rate that the entire star would be used up just in supplying the radiant energy in a period of something of the order of 10 million years. Now that's a very short time on the astronomical time scale. In fact, if all the stars had started shining at one time, there would be no blue stars because they would have used themselves up long since in putting forth the energy that we now see. So they provide clear evidence of the fact that stars are being born at the present time and that they go through evolutionary processes in ways which we are beginning to understand through the application of physical laws. The stars are not eternal. The stars were not all born at one time. They are being born and fading away all the while. New ones are being born right this instant. Occasionally we think that we have caught them in the process of birth and can almost see them being born in a few instances. The constellation of Orion contains many young stars.

The next slide will show you a detailed view of the Orion nebula taken with a large telescope, so you can see what an intricate gaseous mass it is. In the center of it several very hot stars provide the energy which makes it glow. Their ultraviolet light excites the hydrogen gas which is the main constituent of the nebula. There are quite a few of these glowing nebulae in the stellar system, and we use them for a great many kinds of physical and astrophysical studies of the stars. To give you an idea of distances, the Orion nebula is about one and one-half thousand light years distant; it's a rather nearby object as a member of its class of objects.

The next slide shows a different aspect of our stellar survey. The stars that are seen in the sky very often appear in clusters. There is a great tendency for the stars to cluster. And it may well be that the stars are born primarily in groups. This is a fairly well-known group and one that I am sure many of you will recognize, the Pleiades, seen in the winter sky. This cluster is an excellent example displaying the characteristics of a group of stars probably having common birth from dark material in space; those dark clouds we saw earlier are the ones that produce stars. You see what a variety of stars there is. Some are bright, some faint. There is a regular series of relations between the brightness or intrinsic candle power of a star and its color, its size, and many of its other characteristics. It is from clusters of this sort that we learn a great deal about how stars are born and evolve. In addition, you notice the gaseous material around these stars. One sees such nebulosity in clusters that contain hot, blue stars which excite surrounding gas to luminescence. The Pleiades contain several hot, blue stars.

The next slide will show a different type of cluster. There are few of these globular star clusters in our stellar system, but they are certainly spectacular. There are thousands of clusters generally like the Pleiades. There are about 150 globular clusters of this sort within the Milky Way galaxy. These clusters are apparently much older than the galactic star clusters like the Pleiades. The characteristics of the stars that they contain are far different; their brightest stars are red. The brightest stars of objects like the Pleiades are blue. These are very, very dense clusters; the other clusters are always very sparse in their distribution of stars. The clusters like the Pleiades are concentrated in the flat disk of the galaxy--they appear in the Milky Way. Globular clusters like this are distributed around the galaxy and form a kind of halo about it. Most of them are seen in the region of the center of the galaxy and not in the plane of the Milky Way. Regularities in the properties of the stars that form such objects as this--properties that are very different from those of the stars in the Pleiades type of clusters--provide important clues as to the nature and character of the stellar system in which we live.

Individual stars are changing, evolving. I mentioned how blue stars would burn themselves out. Certainly many stars are undergoing evolutionary processes that we see the results of because they throw off masses of gas. The next slide shows a planetary nebula, so-called not because it's a planet but because the early astronomers seeing such objects as disks (the stars all appear as points of light) thought they were looking at planets. If you look carefully at this picture you can see little bits of material where obviously stuff is being blown off and thrown out from little gaseous knots. Such an object as this is born when a star of a certain kind at a certain stage of its evolution throws off a shell of gas. Clearly, stars are changing and evolving rapidly in some instances. There are not many of these; they must represent a rather short-lived process in the course of stellar evolution.

The next slide shows a more violent explosion of a star. This is the Crab nebula which is at a distance of something like 4-1/2 thousand light years. It was seen to explode in the year 1054, and was well recorded in early Chinese Annals. It is possible to locate the object from which the explosion took place. I cannot point it out here because of the complicated involvement of the gaseous mass which was thrown off in the process of the explosion. We have witnessed a number of stellar explosions such as this. The exploding star increases enormously in brightness, reaching a luminosity equal to a billion, billion ordinary stars for a short period of time. Well, more about that object later.

Let me turn now from objects in the galaxy to a much larger question of a different sort. How do the various types of objects we have been looking at form the Milky Way galaxy? The next slide shows a schematic picture of the Milky Way galaxy in which we live. So, imagine now that the beam of light on which we have been riding through the galaxy to see what there is in the system has carried us out to a distance of a million light years. This is what the Milky Way galaxy would look like seen on edge from far outside it. The stars are concentrated in a plane. If we could look down on the system rather than see it from its side as illustrated in this slide, we would see a disk of stars, dust, and gas of spiral form. The system is rotating about an axis perpendicular to the plane of stars. The sun is located in the flattened plane, approximately two-thirds of the way from the center to the edge, a distance of about 35, 000 light years from the center of the system. The plane is not very thick, being only a few hundred light years thick, generally speaking. Most of the objects that we have been looking at in these slides are concentrated in the plane of the galaxy. Many objects, however, form a kind of halo around the galaxy. The globular star clusters in the system, for example, are generally halo objects. They are here represented by these dots forming a large halo around the galaxy. The galaxy is rotating. Out here at the sun's position the galaxy requires about 200 million years to make one circuit. A "stellar year," as opposed to our terrestrial year, is about 200 million years long. Well, there are tremendously interesting things going on in this system. We are beginning to learn about them. The system is throwing gas out of the center. The stars that make up the system are always in a process of evolutionary change. Some stars are exploding; other stars are being born. There is a tremendous churning of materials throughout the system all the time. Stars are not constant, are not fixed, are not eternal at all.

In our arm-chair voyage through space, we are out about a million light years looking back at the galaxy. Now, let's take the jump into deep space --let's look around and see what's out there at the great distances, out many millions of light years from our own stellar system.

The next slide will show another Milky Way like our own. Just to show you that I wasn't fooling you in that schematic picture, here is another neighboring galaxy, another Milky Way system which is very much like our own. It is a couple of million light years away from our own. It's also spinning around its center. It has a bulge in the center, it has dark material and blue stars and clusters and all the other things that we looked at in our own galaxy.

We are not alone; we are one of many.

The next slide will show another of these external galaxies. I show it first as photographed with a very wide-angle camera. This is the Andromeda galaxy--you can see it as a hazy patch of light in the sky with the naked eye if you look in just the right place in the right way. Here you see it in this slide with a large telescope, and you see what an intricate structure it has. It is another whole stellar system like our own galaxy which I was describing earlier. And this galaxy has a couple of companion galaxies also that are like satellites to it, and we have two such satellites also--the Magellanic Clouds which are visible in the Southern Hemisphere. You see in the Andromeda galaxy the structure of dark material, gaseous nebulae, star clusters--you can see them all if you look in sufficient detail--that we found in our own stellar system.

The next few slides show the wide variety of galaxies we find even within our general neighborhood of a few million light years. There is no lack of examples. We see these galaxies in great profusion in every direction in space. Some of the most picturesque systems are those that show beautiful regular spiral structure.

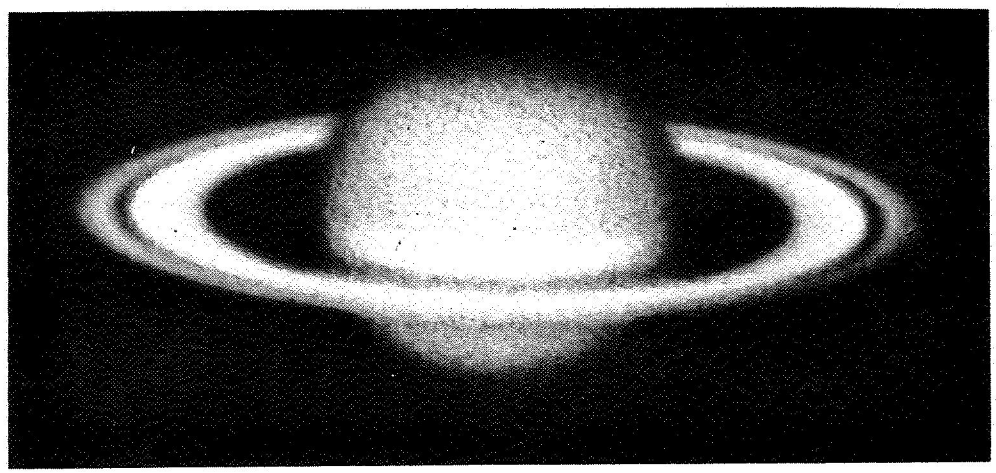
The next slide takes us on another jump into space. Everywhere in space we see galaxies like the ones we have been looking at in these slides. We have been looking at single examples. But galaxies also occur in pairs, multiples, and clusters. In this slide we see many galaxies, fuzzy little patches clustered together, a whole cluster of stellar systems, each like our Milky Way. This cluster is about 40 million light years away. And, as we look out into space, we see clusters of galaxies at ever increasing distances out and out and out. The next one will show you a fainter cluster, a couple of hundred million light years away. The last slide is one where the galaxies are marked because you have to look carefully to see them they are so faint. This cluster is about a billion light years away. And it goes on, and on, and on. Everywhere space is filled with these galaxies. Within each of them stars are being born and evolving; there are in progress all of the processes that I described as going on in our own galactic system. This perhaps will provide you with a view of what we see in optical astronomy. I remind you that this is a view in a very narrow wavelength region, and that what we see is the universe as it is represented by those physical processes (primarily thermal processes) that concentrate radiation mainly in the optical range.

I should tell you a little about what we "see" in the other ranges of the spectrum because other universes--that's too poetic a term--other physical processes in the universe begin to dominate the picture when we start to look in other ranges. What we see seems strange and unusual, but we must become accustomed to an entirely different view of the universe when we look, say, in the radio range. Unfortunately, I can't show you any pictures of radio objects because there is no radio camera, but we have by various processes built up a drawing of what the sky looks like in the radio range. I'll try to describe the radio sky. I have only a few moments left, but perhaps I can give you some impressions of what we see. Let us imagine that we tune our eyes, not to optical light but to radio waves one meter long, instead of a millionth of an inch or so, which is the wavelength of light. Our first surprise would be that, as far as we know, we wouldn't see any stars at all. They all disappear. But, what does appear is the whole Milky Way as a bright sheet of radiance. In fact, the most intense portion of the radio sky lies in the direction of the center of the Milky Way. Relatively, the Milky Way is a blinding illumination for the radio telescope. The sun shows up in the meter wavelength band, but it's pretty faint, and it's also much bigger than it appears in the optical range.

It appears to be two to three times its optical diameter in the radio range. The reason is that the radio radiation comes from hot outer gas, the corona, which surrounds the sun, rather than from the optical surface of the sun. So we see the solar corona in the radio range. Occasionally, as it goes around its yearly circuit, the sun will cut across the Milky Way, and there, contrary to what we see optically, the sun appears against this blinding background of the Milky Way as a dark object because the Milky Way is so much brighter than the sun in this wavelength range. We would see in many parts of the radio sky smaller, very intense sources. These would not coincide with the stars which we normally see with our eyes or that we photograph on photographic plates. They correspond to objects that are shining by other physical processes. For example, the Crab nebula, that old exploding star which we saw earlier, is a very bright radio source. It's a bright radio source because within the Crab nebula there is a magnetic field; those twisted filaments that you saw in the optical picture are perhaps related to the magnetic field carried off in the material thrown out in the process of the explosion. There are also many high energy particles, particularly high energy electrons that were shot out and that are still being shot out, by the star that exploded. Now, the combination of high energy electrons and magnetic field is the clue. When electrons move with very high velocities and circulate around magnetic lines of force, they generate radio waves; hence, the Crab nebula shows up very strongly in radio waves. In fact, at a wavelength of two meters, the physical process that generates the most energy is the motion of high energy particles in magnetic fields. So we begin to see a universe composed of magnetic fields and cosmic rays or cosmic ray electrons in this radio range of the electromagnetic spectrum. In other words, we have to get used to a new universe, dominated by a different kind of process than we normally think of when we look at the sky. We are used to thinking in terms of thermal processes involving stars and the like, but when we observe in the radio range at the longer wavelengths, we must think of other physical processes such as high energy electrons in magnetic fields.

An interesting discovery of recent times is the quasar--the quasi-stellar radio source. Quasars, which I am sure you have heard of since they have made both Time and Life, were first discovered in the radio range and then identified in the optical range. A quasar is exciting because it is, for reasons we do not understand, generating enormous amounts of energy. They appear to be very small in angular extent, like a star, but they are also, according to one theory, and I think probably the right one, very distant. They are the most distant objects that have been observed out to which distances have been assigned at the present time. They appear to be moving away (as is characteristic of all extra-galactic nebulae) at nearly the velocity of light. Now, the universe the optical astronomer has seen and studied all these years is one that is expanding; the distant nebulae all appear to be moving away because of expansion of the universe. There is a relation between the distance of the object and the velocity with which it is observed to be moving away. The more rapidly it is moving, the more distant it is. In the case of the quasars we are seeing out far beyond that faint, nebulous patch of galaxies that we saw on the last picture. We are seeing out to several billion light years distance in the quasars, if indeed they are galaxies--and they very likely are. They must represent then some very early or at least ephemeral stage in the universe and in the formation and evolution of galaxies. Again, it would be impossible to account for the enormous amount of radiation that we see if they had been shining for a very long period, that is, for millions of years. They are putting forth energy--remember I told you about the blue stars that were putting out so much energy they would have burned themselves up if they had gone on for very long--well, these objects are also putting forth energy so that they would have used themselves up if they used nuclear processes to generate their energy. They may not be using nuclear processes, and here is the great importance of this problem. Perhaps we have here some physical process not yet thoroughly explored, not yet understood, some other method of producing energy.

Astronomy is an old science that has always excited interest. It is a topic full of interesting subjects. It is a field full of interesting material. In its modern aspect it is more breathtaking than ever. What we see in the enormous universe outside of the tiny Earth cannot fail to excite us and awe us by its immensity. Thank you very much.



The planet Saturn.